US 89 CORRIDOR PROFILE STUDY

FLAGSTAFF TO UTAH STATE LINE

ADOT WORK TASK NO. MPD 0042-17
ADOT CONTRACT NO. 17-000151766

DRAFT CHAPTERS 4 - 6

DECEMBER 2017

PREPARED FOR:

ARIZONA DEPARTMENT OF TRANSPORTATION

PREPARED BY:

AECOM

This report was funded in part through grants from the Federal Highway Administration, U.S. Department of Transportation. The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data, and for the use or adaptation of previously published material, presented herein. The contents do not necessarily reflect the official views or policies of the Arizona Department of Transportation or the Federal Highway Administration, U.S. Department of Transportation. This report does not constitute a standard, specification, or regulation. Trade or manufacturers' names that may appear herein are cited only because they are considered essential to the objectives of the report. The U.S. government and the State of Arizona do not endorse products or manufacturers.

Table of Contents

List of Figures

List of Tables

Appendices

ACRONYMS & ABBREVIATIONS

AADT	Average Annual Daily Traffic
ADOT	Arizona Department of Transportation
ASLD	Arizona State Land Department
AZTDM	Arizona Travel Demand Model
BCA	Benefit-Cost Analysis
BLM	Bureau of Land Management
BQAZ	Building a Quality Arizona
CCTV	Closed Circuit Television
CR	Cracking Rating
DMS	Dynamic Message Sign
DCR	Design Concept Report
FY	Fiscal Year
HCRS	Highway Condition Reporting System
HERE	Real time traffic conditions database produced by American Digital Cartography Inc.
HPMS	Highway Performance Monitoring System
I-	Interstate
IRI	International Roughness Index
ITS	Intelligent Transportation System
LCCA	Life-Cycle Cost Analysis
LOS	Level of Service
LRTP	Long Range Transportation Plan
MAP 21	Moving Ahead for Progress in the 21st Century
MP	Milepost
MPD	Multimodal Planning Division
NACOG	Northern Arizona Council of Governments
NB	Northbound
NPV	Net Present Value
NTS	Navajo Transit System
OP	Overpass
PES	Performance Effectiveness Score
P2P	Planning to Programming
PDI	Pavement Distress Index
PSR	Pavement Serviceability Rating
PTI	Planning Time Index
RTP	Regional Transportation Plan
SB	Southbound
SHSP	Strategic Highway Safety Plan
SR	State Route
TI	Traffic Interchange
TIP	Transportation Improvement Plan
TPTI	Truck Planning Time Index
TTI	Travel Time Index
TTTI	Truck Travel Time Index
UP	Underpass
US	United States Route
USDOT	United States Department of Transportation
V/C	Volume to Capacity Ratio
V/MT	Vehicle-Miles Travelled
WIM	Weigh-in-Motion

1.0 INTRODUCTION

The Arizona Department of Transportation (ADOT) is the lead agency for this Corridor Profile Study (CPS) of US Route 89 between Flagstaff and Utah Stateline. The study examines key performance measures relative to the US 89 Corridor, and the results of this performance evaluation are used to identify potential strategic improvements. The intent of the corridor profile program, and of ADOT's Planning-to-Programming (P2P) process, is to conduct performance-based planning to identify areas of need and make the most efficient use of available funding to provide an efficient transportation network.

ADOT has already conducted eleven CPS within three separate groupings or rounds.

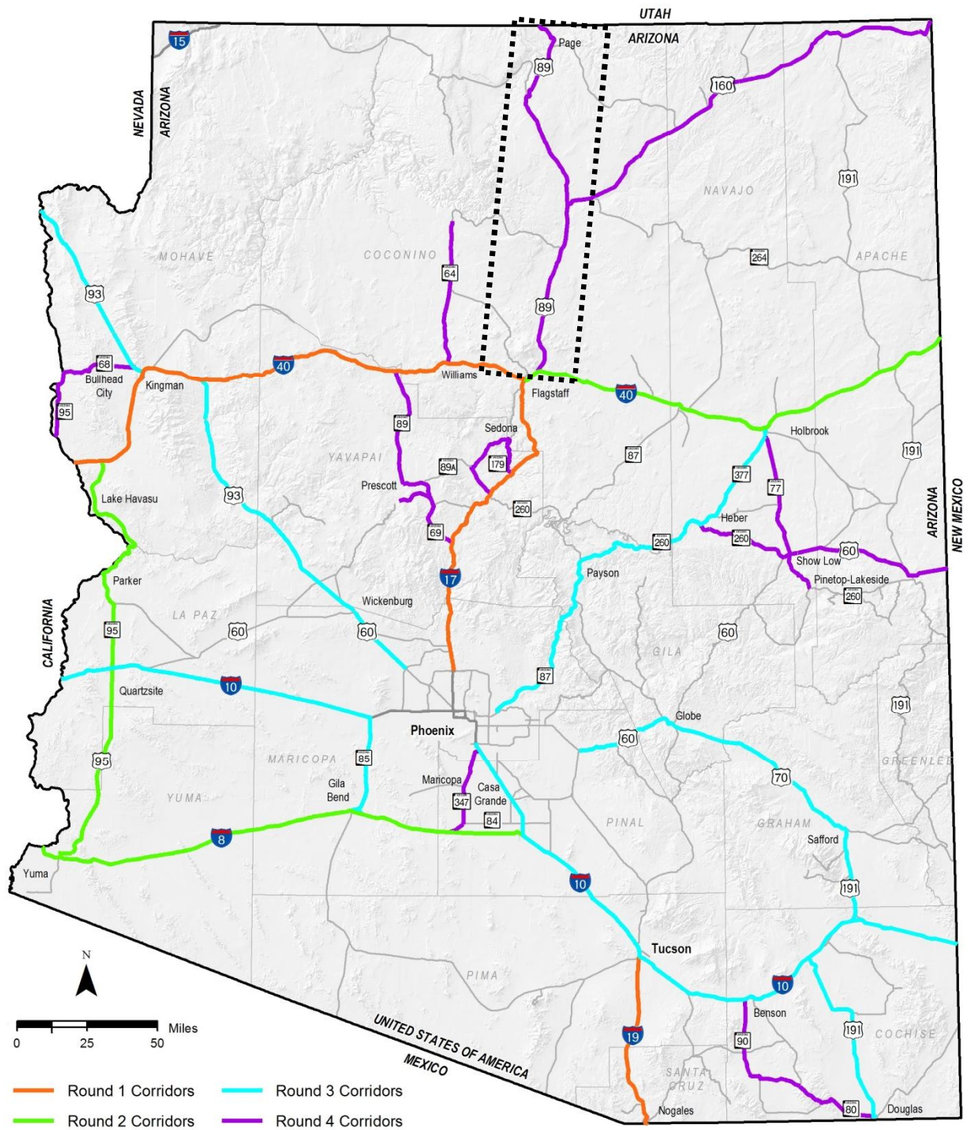
The fourth round (Round 4) of studies began in Spring 2017, and includes:

- US 89: Flagstaff to Utah Stateline
- US 160: US 89 to New Mexico Stateline
- SR 64: I-40 to Grand Canyon National Park
- SR 68: SR 95 to US 93 and SR 95: California Stateline to Nevada Stateline
- SR 69: I-17 to SR 89; Fain Rd: SR 69 to SR 89A; SR 89A: Fain Rd to SR 89; SR 89: SR 89A to I-40
- SR 77: US 60 to SR 377
- SR 90: I-10 to SR 80 and SR 80: SR 90 to US 191
- SR 179: I-17 to SR 89A; SR 89A: SR 179 to SR 260; and SR 260: SR 89A to I-17
- SR 260: SR 277 to SR 73 and US 60: SR 260 to New Mexico Stateline
- SR 347: I-10 to SR 84 and SR 84: SR 347 to I-8

The studies under this program assess the overall health, or performance, of the state's strategic highways. The CPS will identify candidate solutions for consideration in the Multimodal Planning Division's (MPD) P2P project prioritization process, providing information to guide corridor-specific project selection and programming decisions.

The US 89 Corridor, depicted in **Figure 1,** is one of the strategic statewide corridors identified and the subject of this Round 4 CPS.

Figure 1: Corridor Study Area



1.1 Corridor Overview and Location

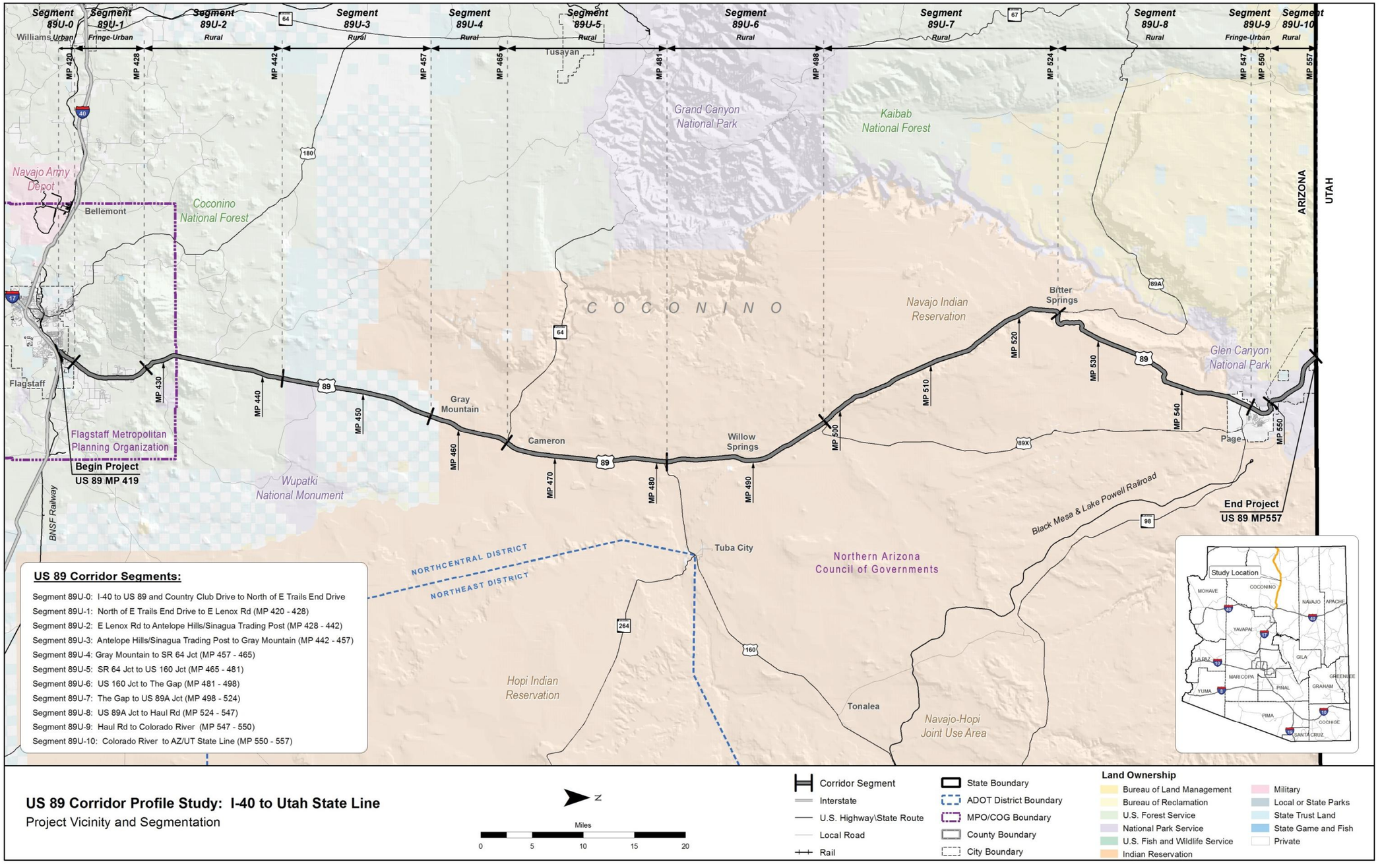
The US 89 Corridor provides an important northeastern connection from Flagstaff, Arizona to economic and recreational opportunities in Northern Arizona and Southern Utah, including the Navajo Nation and Hopi Tribe lands, the eastern entrance to the Grand Canyon, and onto Page and Lake Powell. US 89 is generally a two-lane undivided highway, while the first ten miles of the corridor in the vicinity of Flagstaff is a four-lane undivided highway.

The US 89 Corridor extends from Flagstaff (milepost [MP] 420) to the Utah State Line (MP 557). The corridor is located ADOT's Northcentral District, two planning areas (Flagstaff Metropolitan Planning Organization [FMPO] and Northern Arizona Council of Governments [NACOG]), and Coconino County.

1.2 Corridor Segments

The US 89 Corridor is divided into 10 planning segments to allow for an appropriate level of detailed needs analysis, performance evaluation, and comparison between different segments of the corridor. Segmentation by similar characteristics (e.g., urban/rural surroundings, road width, traffic volumes) allowed the analysis to highlight anomalies or instances of poor performance within the context of each segment. The corridor is segmented at logical breaks where the context changes due to differences in characteristics such as terrain, daily traffic volumes, or roadway typical section. Additional segment breaks may occur at major intersections or junctions, where the corridor transitions from rural to urban environments, other similar operating environments, maintenance sections, and at jurisdictional changes. Corridor segments are shown in **Figure 2**.

Figure 2: Corridor Location and Segments



2.0 CORRIDOR PERFORMANCE

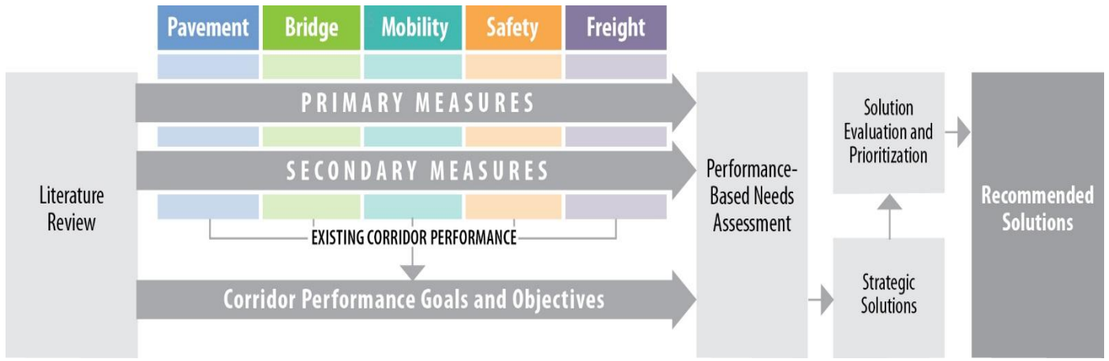
A series of performance measures is used to assess the corridor. The results of the performance evaluations are used to define corridor needs relative to the long term goals and objectives for the corridor.

2.1 Corridor Performance Framework

This study uses a performance-based process to define baseline corridor performance, diagnose corridor needs, develop corridor solutions, and prioritize strategic corridor investments. In support of this objective, a framework for the performance-based process was developed through a collaborative process involving ADOT and the CPS consultant teams.

Figure 3 illustrates the performance framework, which includes a two-tiered system of performance measures (primary and secondary) to evaluate baseline performance.

Figure 3: Corridor Profile Performance Framework



The following five performance areas guide the performance-based corridor analyses:

- Pavement
- Bridge
- Mobility
- Safety
- Freight

The performance measures include five primary measures: Pavement Index, Bridge Index, Mobility Index, Safety Index, and Freight Index. Additionally, a set of secondary performance measures provides for a more detailed analysis of corridor performance. **Table 1** provides the complete list of primary and secondary performance measures for each of the five performance areas.

Table 1: Corridor Performance Measures

Performance Area	Primary Measure	Secondary Measures
Pavement	**Pavement Index** Based on a combination of International Roughness Index and cracking	· Directional Pavement Serviceability · Pavement Failure · Pavement Hot Spots
Bridge	**Bridge Index** Based on lowest of deck, substructure, superstructure and structural evaluation rating	· Bridge Sufficiency · Functionally Obsolete Bridges · Bridge Rating · Bridge Hot Spots
Mobility	**Mobility Index** Based on combination of existing and future daily volume-to-capacity ratios	· Future Congestion · Peak Congestion · Travel Time Reliability · Multimodal Opportunities
Safety	**Safety Index** Based on frequency of fatal and incapacitating injury crashes	· Directional Safety Index · Strategic Highway Safety Plan Emphasis Areas · Crash Unit Types · Safety Hot Spots
Freight	**Freight Index** Based on bi-directional truck planning time index	· Recurring Delay · Non-Recurring Delay · Closure Duration · Bridge Vertical Clearance · Bridge Vertical Clearance Hot Spots

Each of the primary and secondary performance measures is comprised of one or more quantifiable indicators. A three-level scale was developed to standardize the performance scale across the five performance areas, with numerical thresholds specific to each performance measure:

Good/Above Average Performance – Rating is above the identified desirable/average range

Fair/Average Performance – Rating falls within the identified desirable/average range

Poor/Below Average Performance – Rating is below the identified desirable/average range

2.2 Corridor Performance Summary

Based on the results presented in Table 2 (and the previous submittal of Chapters 1 – 3), the following general observations were made related to the performance of the US 89 Corridor:

- The pavement performance is generally in “good” except at a few isolated locations.
- The bridge performance is generally in “fair” condition overall, however there are very few bridges along the corridor.
- The general mobility indices along the corridor have “good” performance where most are also showing very little recurring and non-recurring delays along the corridor. The bicycle accommodation, however, is in “poor” condition.
- The closures along the corridor are generally lower than the statewide average for both the closure frequency and duration, however there are a few outliers for duration, primarily due to the extended closure of segment 8.
- Overall, based on the weighted average of the Safety Index, the corridor performs “above average”. The % of SHSP related crashes shows “poor” performance.

Figure 4 shows the percentage of the US 89 Corridor that rates either “good/above average performance”, “fair/average performance”, or “poor/below average” performance for each primary measure. Approximately 98% of the corridor shows “good” performance in the Pavement Index. For the Bridge Index, 55% of the corridor shows “good” performance, and 27% shows “fair” performance. 100% of the corridor shows “good” performance in Mobility. The majority of the corridor (59%) for the Safety index shows “above average” performance, while 10% of the corridor shows “average” performance, and 31% of the corridor shows “poor” performance. For the Freight Index, approximately 78% of the corridor shows “good” performance while 22% shows “poor” performance.

The lowest performance along the US 89 Corridor generally occurs in the Safety performance area while the Pavement and Mobility show the highest performance.

Table 2 shows a summary of corridor performance for all primary measures and secondary measure indicators for the US 89 Corridor. A weighted corridor average rating (based on the length of the segment) was calculated for each primary and secondary measure.

Figure 4: Performance Summary by Primary Measure

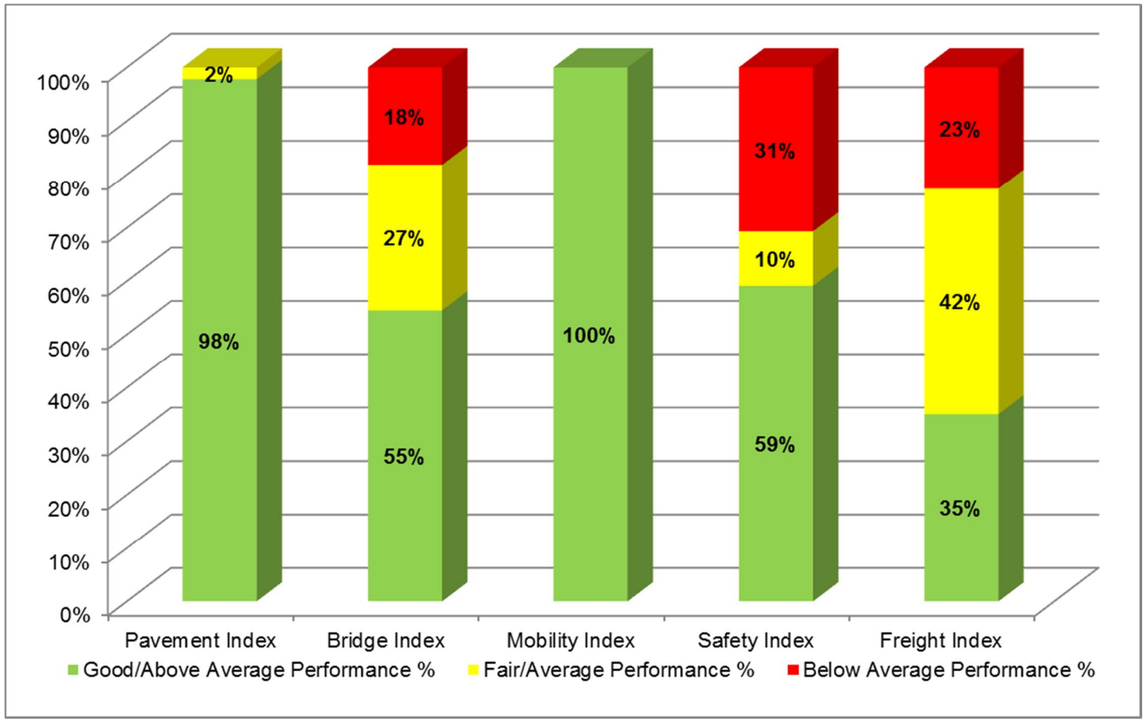


Table 2: Corridor Performance Summary by Segment and Performance Measure

Segment	Length (miles)	Pavement Performance Area				Bridge Performance Area				Mobility Performance Area											
		Pavement Index	Directional PSR		Pavement Failure	Bridge Index	Bridge Sufficiency	Bridge Rating	% Deck Area Functionally Obsolete	Mobility Index	Future Daily V/C	Existing Peak Hour V/C		Closure Extent (instances/milepost /year/mile)		Directional TTI (all vehicles)		Directional PTI (all vehicles)		% Bicycle Acc.	% Non-Single Occupancy Vehicle (SOV) Opportunities
			NB	SB								NB	SB	NB	SB	NB	SB	NB	SB		
89U-1*[1]	8	4.29	4.19	3.04	0.0%	No Bridges in Segment				0.52	0.63	0.36	0.38	0.53	0.10	1.12	1.11	2.23	2.29	19%	20.3%
89U-2^[2]	14	4.02	3.70	4.04	0.0%	No Bridges in Segment				0.15	0.20	0.09	0.09	0.25	0.01	1.02	1.03	1.24	1.42	97%	18.1%
89U-3^[2]	15	3.73	3.47	3.28	0.0%	No Bridges in Segment				0.26	0.32	0.21	0.21	0.00	0.04	1.00	1.01	1.14	1.25	89%	14.2%
89U-4^[2]	8	3.64	3.45	3.45	12.5%	No Bridges in Segment				0.28	0.35	0.19	0.19	0.00	0.03	1.11	1.17	2.38	2.16	94%	6.3%
89U-5*[2]	16	3.66	3.35	3.35	12.5%	6.80	86.40	5.00	8.5%	0.37	0.46	0.24	0.24	0.13	0.05	1.10	1.13	1.74	2.07	75%	8.8%
89U-6^[2]	17	4.04	3.73	3.73	0.0%	4.46	58.03	4.00	0.0%	0.16	0.19	0.15	0.14	0.02	0.01	1.03	1.01	1.50	1.28	99%	11.1%
89U-7^[2]	26	4.01	3.85	3.85	0.0%	6.00	77.10	6.00	0.0%	0.11	0.15	0.06	0.06	0.03	0.02	1.01	1.05	1.53	1.60	88%	9.3%
89U-8^[2]	23	3.72	3.71	3.71	8.7%	6.00	73.10	6.00	0.0%	0.28	0.34	0.17	0.17	0.31	0.09	1.21	1.23	2.69	2.92	2%	11.1%
89U-9*[1]	3	2.98	3.19	3.19	66.7%	6.00	67.70	6.00	0.0%	0.45	0.55	0.30	0.30	0.07	0.07	1.30	1.38	2.86	3.16	91%	4.9%
89U-10^[2]	7	3.82	3.86	3.86	0.0%	No Bridges in Segment				0.27	0.33	0.12	0.12	0.06	0.00	1.17	1.18	2.40	2.43	3%	4.9%
Weighted Corridor Average		3.86	3.68	3.63	5.1%	6.15	77.49	5.40	5%	0.25	0.32	0.17	0.17	0.14	0.04	1.08	1.10	1.84	1.93	66.5%	11.3%
SCALES																					
Performance Level		Non-Interstate								Urban (Rural)						Uninterrupted (Interrupted)				All	
Good/Above Average		> 3.50		< 5%		> 6.5	> 80	> 6	< 12%	< 0.71 (< 0.56)				< 0.22		< 1.15 (1.30)		<1.30 (3.00)		> 90%	> 17%
Fair/Average		2.90 - 3.50		5% - 20%		5.0 - 6.5	50 - 80	5 – 6	12% - 40%	0.71 - 0.89 (0.56 - 0.76)				0.22 – 0.62		1.15-1.33 (1.30-2.00)		1.30-1.50 (3.00-6.00)		60% - 90%	11% - 17%
Poor/Below Average		< 2.90		> 20%		< 5.0	< 50	< 5	> 40 %	> 0.89(> 0.76)				> 0.62		> 1.33 (2.00)		>1.50 (6.00)		< 60%	< 11%

^Uninterrupted Flow Facility
*Interrupted Flow Facility

[1]Urban Operating Environment
[2]Rural Operating Environment

Table 2: Corridor Performance Summary by Segment and Performance Measure (continued)

Segment	Length (miles)	Safety Performance Area				Freight Performance Area							
		Safety Index	Directional Safety Index		% of Fatal + Incapacitating Injury Crashes Involving SHSP Top 5 Emphasis Areas Behaviors	Freight Index	Directional TTI (trucks only)		Directional PTI (trucks only)		Closure Duration (mins/milepost closed/year/mile)		Bridge Vertical Clearance (feet)
			NB	SB			NB	SB	NB	SB	NB	SB	
89U-1*[a]	8	0.40	0.76	0.04	17%	0.42	1.19	1.16	2.66	2.11	2,620.5	18.2	No UP
89U-2^[b]	14	1.13	2.01	0.25	31%	0.68	1.10	1.16	1.38	1.58	1,466.1	1.1	No UP
89U-3^[c]	15	0.05	0.10	0.00	Insufficient Data	0.76	1.05	1.11	1.22	1.40	0.0	6.6	No UP
89U-4^[c]	8	0.77	1.53	0.00	Insufficient Data	0.38	1.22	1.32	2.70	2.54	0.0	3.0	No UP
89U-5*[c]	16	1.43	1.48	1.38	Insufficient Data	0.55	1.14	1.20	1.65	1.99	17.7	7.9	No UP
89U-6^[c]	17	0.48	0.11	0.86	Insufficient Data	0.77	1.07	1.06	1.29	1.30	7.1	2.5	No UP
89U-7^[c]	26	0.04	0.08	0.00	Insufficient Data	0.70	1.05	1.07	1.43	1.41	8.4	1.5	No UP
89U-8^[c]	23	1.19	1.29	1.09	71%	0.41	1.27	1.31	2.63	2.27	175,175.6	17.0	No UP
89U-9*[c]	3	2.49	0.51	4.47	17%	0.28	1.40	1.43	3.19	4.09	11.5	192.5	No UP
89U-10*[c]	7	0.12	0.12	0.12	Insufficient Data	0.48	1.21	1.19	2.01	2.14	10.7	0.0	No UP
Weighted Corridor Averages		0.68	0.79	0.58	34%	0.59	1.14	1.17	1.83	1.83	29,717.2	10.6	No UP
SCALES													
Performance Level		2 or 3 or 4 Lane Divided, 4 or 5 Undivided, 2 or 3 Lane Undivided			Uninterrupted (Interrupted)						All		
Good/Above Average		a < 0.77 b < 0.80 c < 0.94		a < 44% b < 42% c < 51%	> 0.77(0.33)		<1.15(1.30)		<1.30(3.00)		< 44.18		> 16.5
Fair/Average		a 0.77 – 1.23 b 0.80 – 1.20 c 0.94 – 1.06		a 44% - 54% b 42% - 51% e 51% - 58%	0.67 - 0.77 (0.17-0.33)		1.15-1.33(1.30-2.00)		1.30-1.50(3.00-6.00)		44.18 -124.86		16.0-16.5
Poor/Below Average		a > 1.23 b > 1.20 c > 1.06		a > 54% b > 51% c > 58%	< 0.67(0.17)		>1.33(2.00)		>1.50(6.00)		> 124.86		< 16.0

^Uninterrupted Flow Facility
*Interrupted Flow Facility

[a]4 Lane Freeway with Daily Volume < 25,000
[b]4 Lane Freeway with Daily Volume > 25,000
[c]2 or 3 or 4 Lane Divided Highway
[d]4 or 4 Lane Undivided Highway
[e] 2 or 3 Lane Undivided Highway

3.0 NEEDS ASSESSMENT

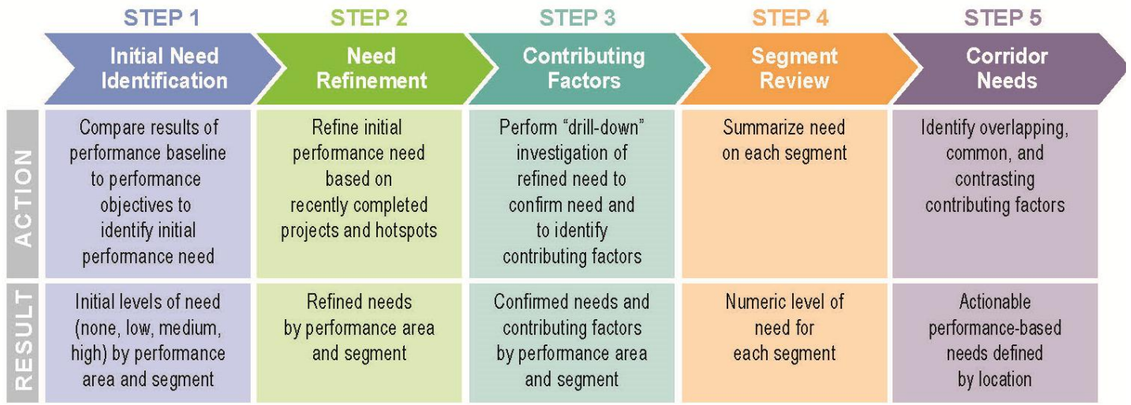
3.1 Needs Assessment Process

The following guiding principles were used as an initial step in developing a framework for the performance-based needs assessment process:

- Corridor needs are defined as the difference between the corridor performance and the performance objectives
- The needs assessment process should be systematic, progressive, and repeatable, but also allow for engineering judgment where needed
- The process should consider all primary and secondary performance measures developed for the study
- The process should develop multiple need levels including programmatic needs for the entire length of the corridor, performance area-specific needs, segment-specific needs, and location-specific needs (defined by MP limits)
- The process should produce actionable needs that can be addressed through strategic investments in corridor preservation, modernization, and expansion

The performance-based needs assessment process is illustrated in **Figure 5.**

Figure 5: Needs Assessment Process



The needs assessment compares baseline corridor performance with performance objectives to provide a starting point for the identification of performance needs. This mathematical comparison results in an initial need rating of None, Low, Medium, or High for each primary and secondary performance measure. An illustrative example of this process is shown in **Figure 6.**

Figure 6: Initial Need Ratings in Relation to Baseline Performance (Bridge Example)

Performance Thresholds	Performance Level	Initial Level of Need	Description
6.5	Good	None	All levels of Good and top 1/3 of Fair (>6.0)
	Good		
	Good		
	Fair		
	Fair	Low	Middle 1/3 of Fair (5.5-6.0)
5.0	Fair	Medium	Lower 1/3 of Fair and top 1/3 of Poor (4.5-5.5)
	Poor		
	Poor	High	Lower 2/3 of Poor (<4.5)
	Poor		

**A segment need rating of 'None' does not indicate a lack of needed improvements; rather, it indicates that the segment performance score exceeds the established performance thresholds and strategic solutions for that segment will not be developed as part of this study.*

The initial level of need for each segment is refined to account for hot spots and recently completed or under construction projects, resulting in a final level of need for each segment. The final levels of need for each primary and secondary performance measure are combined to produce a weighted final need rating for each segment. A detailed review of available data helps identify contributing factors to the need and if there is a high level of historical investment.

3.2 Summary of Corridor Needs

The needs in each performance area are shown in **Table 3** and summarized below:

Pavement Needs

- The Pavement Performance Area is an emphasis area for US 89;
- Five of the ten segments (89U-1, 89U-3, 89U-4, 89U-5, and 89U-8) of the US 89 Corridor exhibit a Low level of Pavement need
- All segments showed a “Low” level of historical investment, except 89U-5 which showed a “high” level of historical investment.

Bridge Needs

- The Bridge Performance Area is not an emphasis area for US 89.
- Two of the ten segments (89U-5 and 89U-9) exhibit a low level of need.
- One of the ten segments (89U-7) exhibits a high level of need.
- None of the bridges exhibit historical issues.

Mobility Needs

- The Mobility Performance Area is an emphasis area for US 89.
- Eight segments (89U-1, 89U-2, 89U-4-8, and 89U-10) exhibit a Low level of need.

Safety Needs

- The Safety Performance Area is an emphasis area for US 89.
- Safety needs exist on five of the ten segments.
- Three of the ten segments (89U-5, 89U-8 and 9) exhibit a High level of need.
- One segment (89U-4) exhibits a Low level of need.

Freight Needs

- The Freight Performance Area is not an emphasis area for US 89.
- Three of the ten segments (89U-2, 89U-4, and 89U-8) exhibit a “High” level of need.
- Four of the ten segments (89U-1, 89U-3, 89U-7, and 89U-9) exhibit a “Low” level of need.
- Similar to Mobility, 100% of road closures are due to incidents/accidents and impact freight performance

Overlapping Needs

This section identifies overlapping performance needs on the US 89 Corridor, which provides guidance to develop strategic solutions that address more than one performance area with elevated (i.e., Medium or High) levels of need. Completing projects that address multiple needs presents the opportunity to more effectively improve overall performance. A summary of the overlapping needs that relate to locations with elevated levels of need is provided below:

- Segment 9 shows elevated needs in the Pavement and Safety performance areas.
- Segments 89U-2 and 89U-8 show elevated needs in the Safety and Freight performance areas.

Table 3: Summary of Needs by Segment

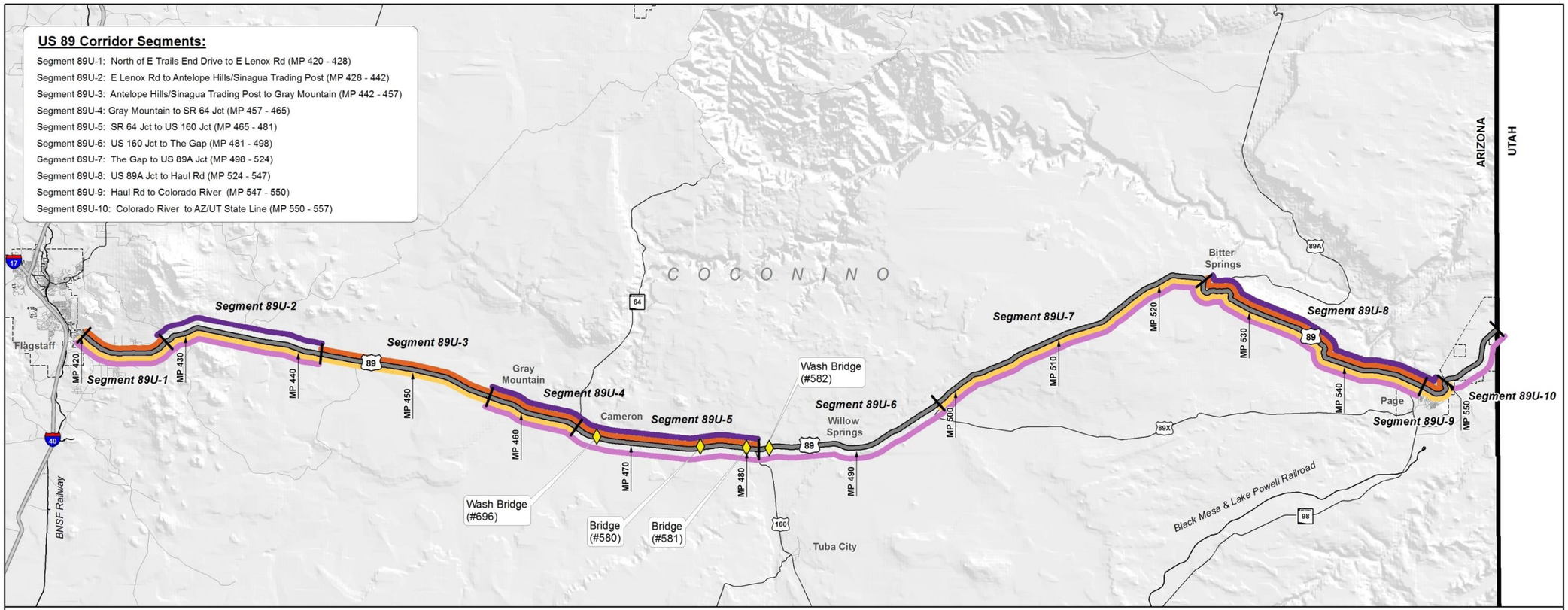
Performance Area	Segment Number and Mileposts (MP)									
	89U-1	89U-2	89U-3	89U-4	89U-5	89U-6	89U-7	89U-8	89U-9	89U-10
	MP 420-428	MP 428-442	MP 442-457	MP 457-465	MP 465-481	MP 481-498	MP 498-524	MP 524-547	MP 547-550	MP 550-557
Pavement*	Low	None+	Low	Low	Low	None+	None+	Low	High	None+
Bridge	None+	None+	None+	None+	Low	High	None+	None+	Low	None+
Mobility*	Low	Low	None+	Low	Low	Low	Low	Low	None+	Low
Safety*	None+	Medium	None+	Low	High	None+	None+	High	High	None+
Freight	Low	High	Low	High	None+	None+	Low	High	Low	None+
Average Need (0-3)	**0.62**	**1.15**	**0.38**	**1.15**	**1.31**	**0.69**	**0.38**	**1.62**	**1.69**	**0.23**

**A segment need rating of 'None' does not indicate a lack of needed improvements; rather, it indicates that the segment performance score exceeds the established performance thresholds and strategic solutions for that segment will not be developed as part of this study.*

+ Identified as an emphasis area for the US 89 Corridor.

Scale	
None	< 0.1
Low	0.1 - 1.0
Medium	1.0 - 2.0
High	> 2.0

Figure 7: Corridor Needs Summary



Performance Area	89U-1	89U-2	89U-3	89U-4	89U-5	89U-6	89U-7	89U-8	89U-9	89U-10
	MP 420-428	MP 428-442	MP 442-457	MP 457-465	MP 465-481	MP 481-498	MP 498-524	MP 524-547	MP 547-550	MP 550-557
Pavement (Emphasis Area)	Low	None*	Low	Low	Low	None*	None*	Low	High	None*
Bridge	None*	None*	None*	None*	Low	High	None*	None*	Low	None*
Mobility (Emphasis Area)	Low	Low	None*	Low	Low	Low	Low	Low	None*	Low
Safety (Emphasis Area)	None*	Medium	None*	Low	High	None*	None*	High	High	None*
Freight	Low	High	Low	High	None*	None*	Low	High	Low	None*
Average Need	**0.62**	**1.15**	**0.38**	**1.15**	**1.31**	**0.69**	**0.38**	**1.62**	**1.69**	**0.23**

*A segment need rating of 'None' does not indicate a lack of needed improvements; rather, it indicates that the segment performance score exceeds the established performance thresholds and strategic solutions for that segment will not be developed as part of this study.

US 89 Corridor Profile Study: I-40 to Utah State Line
Corridor Needs Summary

N
Miles
0 5 10 15 20

Corridor Segment
Interstate
U.S. Highway\State Route
Local Road
Rail
State Boundary
County Boundary
City Boundary

NEEDS SUMMARY
SAFETY
BRIDGE
PAVEMENT
FREIGHT
MOBILITY

LEVEL OF NEED

None*	< 0.1
Low	0.1 - 1.0
Medium	1.0 - 2.0
High	> 2.0

4.0 STRATEGIC SOLUTIONS

The principal objective of the CPS is to identify strategic solutions (investments) that are performance-based to ensure that available funding resources are used to maximize the performance of the State's key transportation corridors. One of the first steps in the development of strategic solutions is to identify areas of elevated levels of need (i.e., Medium or High). Addressing areas of Medium or High need will have the greatest effect on corridor performance and are the focus of the strategic solutions. Segments with Medium or High needs and specific locations of hot spots are considered strategic investment areas for which strategic solutions should be developed. Segments with lower levels of need or without identified hot spots are not considered candidates for strategic investment and are expected to be addressed through other ADOT programming processes. The US 89 strategic investment areas (resulting from the elevated needs) are shown in **Figure 8**.

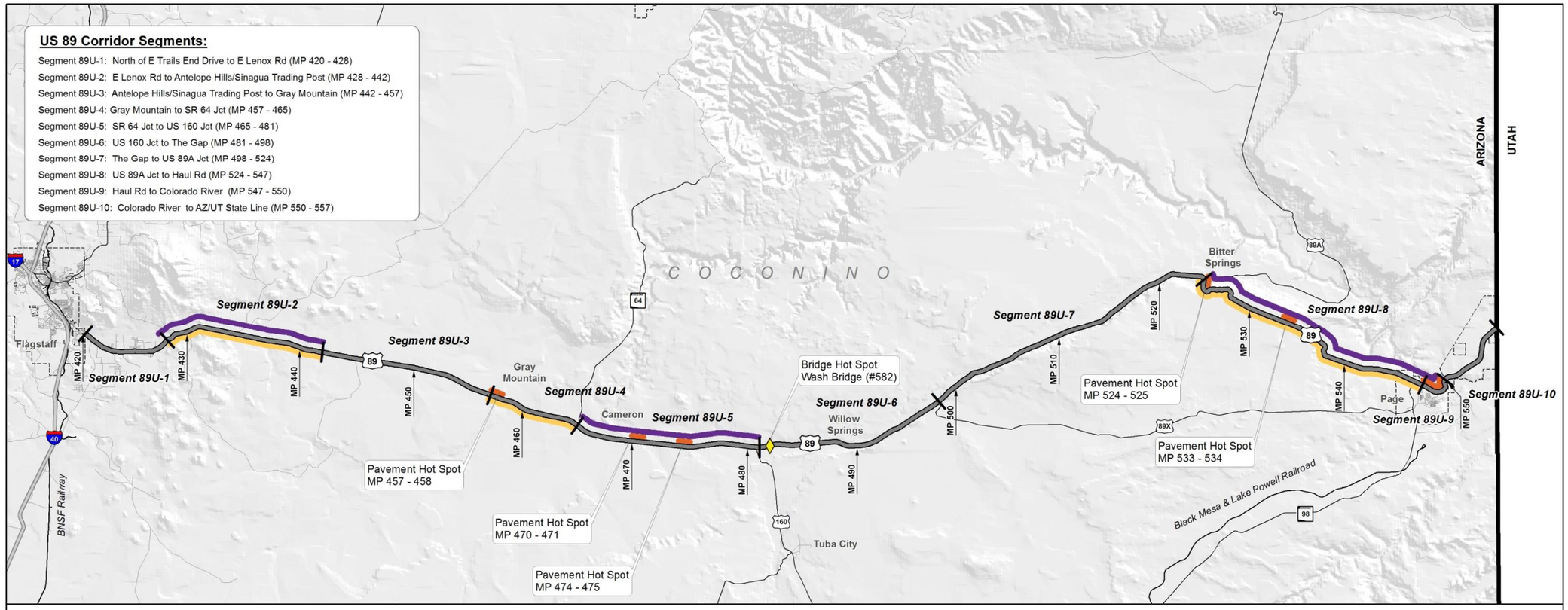
4.1 Screening Process

This section examines qualifying strategic needs and determines if the needs in those locations require action. In some cases, needs that are identified do not advance to solutions development and are screened out from further consideration because they have been or will be addressed through other measures including:

- A project is programmed to address this need
- The need is a result of a Pavement or Bridge hot spot that does not show historical investment or rating issues; these hot spots will likely be addressed through other ADOT programming means.
- A bridge is not a hot spot but is located within a segment with a Medium or High level of need; this bridge will likely be addressed through current ADOT bridge maintenance and preservation programming processes.
- The need is determined to be non-actionable (i.e., cannot be addressed through an ADOT project)
- The conditions/characteristics of the location have changed since the performance data was collected that was used to identify the need

Table 4 notes if each potential strategic need advanced to solution development, and if not, the reason for screening the potential strategic need out of the process. Locations advancing to solutions development are marked with Yes (Y); locations not advancing are marked with No (N) and highlighted. This screening table provides specific information about the needs in each segment that will be considered for strategic investment. The table identifies the level of need – either Medium or High segment needs, or segments without Medium or High level of need that have a hot spot. Each area of need is assigned a location number in the screening table to help document and track locations considered for strategic investment.

Figure 8: Strategic Investment Areas



Performance Area	89U-1	89U-2	89U-3	89U-4	89U-5	89U-6	89U-7	89U-8	89U-9	89U-10
	MP 420-428	MP 428-442	MP 442-457	MP 457-465	MP 465-481	MP 481-498	MP 498-524	MP 524-547	MP 547-550	MP 550-557
Pavement (Emphasis Area)	-	-	-	Hot Spot	Hot Spot	-	-	Hot Spot	High	-
Bridge	-	-	-	-	-	High	-	-	-	-
Mobility (Emphasis Area)	-	-	-	-	-	-	-	-	-	-
Safety (Emphasis Area)	-	Medium	-	-	High	-	-	High	High	-
Freight	-	High	-	High	-	-	-	High	-	-

Notes: Figure shows strategic investment areas, which are segments with Medium and High levels of need and locations of hot spots.
A "-" symbol indicates a segment level of need of Low or None, which is not considered strategic.

US 89 Corridor Profile Study: I-40 to Utah State Line
Strategic Investment Areas

N
Miles
0 5 10 15 20

Corridor Segment
Interstate
U.S. Highway\State Route
Local Road
Rail
State Boundary
County Boundary
City Boundary

PERFORMANCE AREA NEEDS
SAFETY
BRIDGE
PAVEMENT
FREIGHT
MOBILITY

LEVEL OF NEED

None*	< 0.1
Low	0.1 - 1.0
Medium	1.0 - 2.0
High	> 2.0

Table 4: Strategic Investment Area Screening

Segment # and MP	Level of Strategic Need					Location #	Type	Need Description	Advance (Y/N)	Screening Description
	Pavement	Bridge	Mobility	Safety	Freight					
89U-1 MP 420-428	-	-	-	-	-	No strategic needs identified				
89U-2 MP 428-442	-	-	-	Medium	High	L1	Safety	Crash trends show overturning (54%), involving a single vehicle (69%), run-off-road (58%), and occurring in dark/unlighted conditions (54%)	Y	
						L2	Freight	Freight needs primarily associated with elevated Directional PTI levels in the southbound direction	N	The elevated travel times are likely due to the uphill grade (which already has a climbing lane) and possibly the mining land uses located west of US 89.
89U-3 MP 442-457	-	-	-	-	-	No strategic needs identified				
89U-4 MP 457-465	Hot Spot	-	-	-	High	L3	Pavement	Hot Spots MP 457-458 with Low level of historical investment	N	Does not meet criteria for historical investment
						L4	Freight	Freight needs primarily associated with elevated Directional PTI levels in both directions	N	Elevated NB/SB PTI values are at north end of segment 4, where there was construction and where the intersection/roundabout is located, and where there are several gas stations/restaurants/shops.
89U-5 MP 465-481	Hot Spot	-	-	High	-	L5	Safety	Crash trends show collision with motor vehicle (67%), occurring in dark/unlighted conditions (38%), run off the road (51%), and crossing the center line (38%)	Y	
						L6	Pavement	Hot spots MP 470-471, 474-475 with High level of historical investment	Y	
89U-6 MP 481-498	-	High	-	-	-	L7	Bridge	Wash Bridge (MP 481.89)(#582) has current deck, substructure, and superstructure ratings of 5, and a structural evaluation rating of 4	N	Bridge does not meet criteria for historical investment
89U-7 MP 498-524	-	-	-	-	-	No strategic needs identified				
89U-8 MP 524-547	Hot Spot	-	-	High	High	L8	Pavement	Hot Spots MP 524-525, and MP 533-534 with Low level of historical investment	N	Does not meet criteria for historical investment
						L9	Safety	Crash trends show collision with motor vehicle (57%), overturning (43%), occurring in dark/unlighted conditions (57%), and crossing the center line (57%)	Y	
						L10	Freight	Freight needs primarily associated with elevated Directional PTI levels in both directions	Y	
89U-9 MP 547-550	High	-	-	High	-	L11	Pavement	Hot Spots MP 547-548 and 549-550 with Low Level of historical investment	N	Does not meet criteria for historical investment
						L12	Safety	Crash trends show collision with motor vehicle (67%), failure to yield right-of-way (50%), and angle collisions (67%)	Y	
89U-10 MP 550-557	-	-	-	-	-	No strategic needs identified				

Legend: Strategic investment area screened out from further consideration.

4.2 Candidate Solutions

For each elevated need within a strategic investment area that is not screened out, a candidate solution is developed to address the identified need. Each candidate solution is assigned to one of the following three P2P investment categories based on the scope of the solution:

- Preservation
- Modernization
- Expansion

Documented performance needs serve as the foundation for developing candidate solutions for corridor preservation, modernization, and expansion. Candidate solutions are not intended to be a substitute or replacement for traditional ADOT project development processes where various ADOT technical groups and districts develop candidate projects for consideration in the performance-based programming in the P2P process. Rather, these candidate solutions are intended to complement ADOT's traditional project development processes through a performance-based process to address needs in one or more of the five performance areas of Pavement, Bridge, Mobility, Safety, and Freight. Candidate solutions developed for the US 89 Corridor will be considered along with other candidate projects in the ADOT statewide programming process.

Characteristics of Strategic Solutions

Candidate solutions should include some or all of the following characteristics:

- Do not recreate or replace results from normal programming processes
- May include programs or initiatives, areas for further study, and infrastructure projects
- Address elevated levels of need (High or Medium) and hot spots
- Focus on investments in modernization projects (to optimize current infrastructure)
- Address overlapping needs
- Reduce costly repetitive maintenance
- Extend operational life of system and delay expansion
- Leverage programmed projects that can be expanded to address other strategic elements
- Provide measurable benefit

Candidate Solutions

A set of 7 candidate solutions are proposed to address the identified needs on the US 89 Corridor.

Table 5 identifies each strategic location that has been assigned a candidate solution with a number (e.g., CS89U.1, CS89U.2, etc.). Each candidate solution is comprised of one or more components to address the identified needs. The assigned candidate solution numbers are linked to the location number and provide tracking capability through the rest of the process. The locations of proposed solutions are shown on the map in **Figure 9**.

Candidate solutions developed to address an elevated need in the Pavement or Bridge performance area will include two options; rehabilitation or full replacement. These solutions are initially evaluated through a Life-Cycle Cost Analysis (LCCA) to provide insights into the cost-effectiveness of these options so a recommended approach can be identified. Candidate solutions developed to address an elevated need in the Mobility, Safety, or Freight performance areas are advanced directly to the Performance Effectiveness Evaluation. In some cases, there may be multiple solutions identified to address the same area of need.

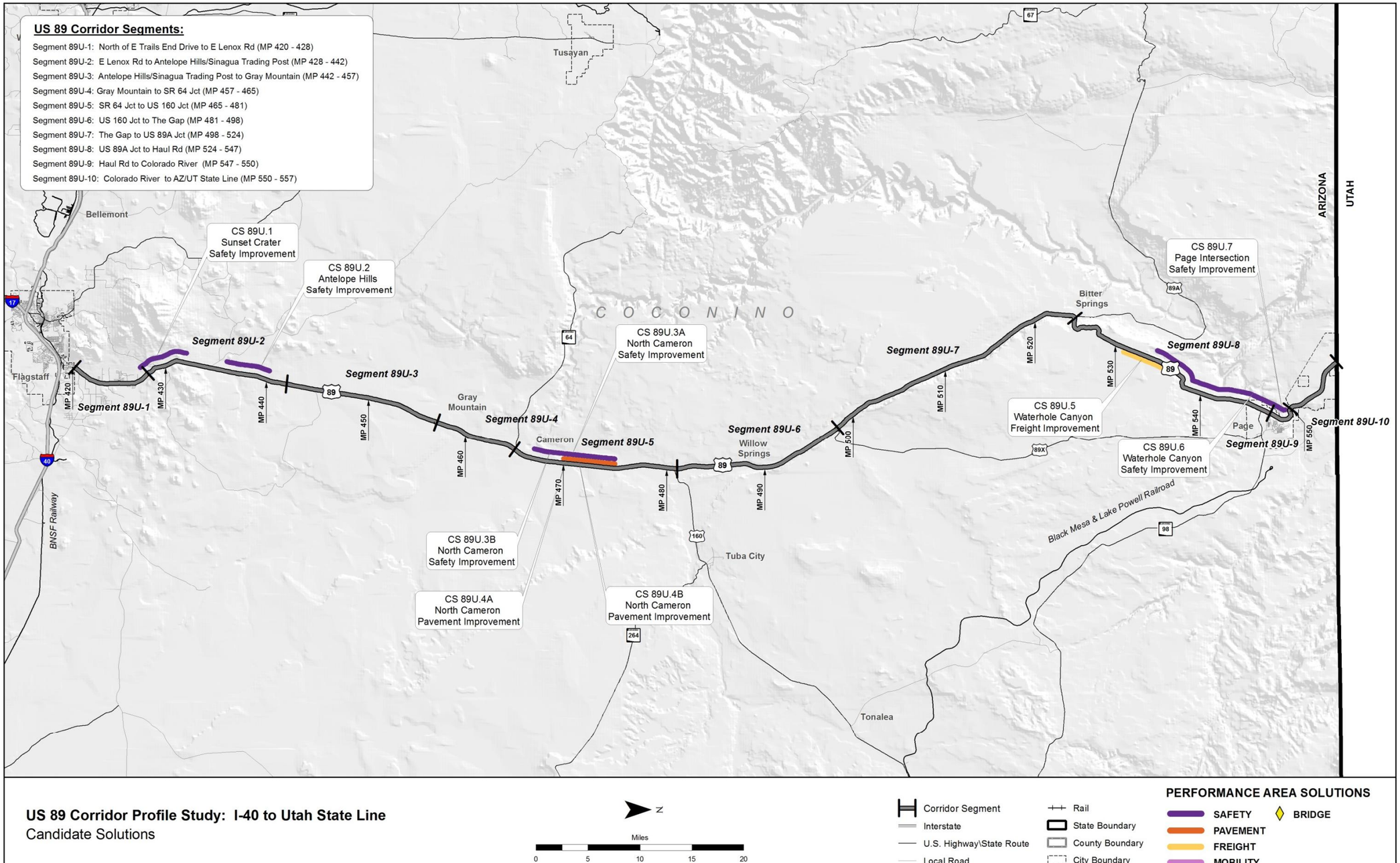
Candidate solutions that are recommended to expand or modify the scope of an already programmed project are noted and are not advanced to solution evaluation and prioritization. These solutions are directly recommended for programming.

Table 5: Candidate Solutions

Candidate Solution #	Segment #	Location #	Beg Milepost	End Milepost	Candidate Solution Name	Option*	Scope	Investment Category Preservation [P] Modernization [M] Expansion [E]
CS 89U.1	89U-2	L1	428	432	Sunset Crater Safety Improvement	-	Install high visibility striping and delineators, raised pavement markers, and rumble strips Install chevrons on curves	M
CS 89U.2	89U-2	L1	436	440	Antelope Hills Safety Improvement	-	Install high visibility striping and delineators, raised pavement markers, and rumble strips Install chevrons on curves Install roadway lighting	M
CS 89U.3	89U-5	L5	467	475	North Cameron Safety Improvement	A	Widen/reconstruct roadway to provide 4-lane divided section	E
						B	Install high visibility striping and delineators, raised pavement markers, and rumble strips Construct SB passing lane MP 467.5 – 468.5 Widen shoulders MP 467–468, MP 469–470, MP 471-472, MP 474-475	M
CS 89U.4	89U-5	L6	470	475	North Cameron Pavement Improvement	A B	Repair/rehabilitate pavement Replace pavement	P M
CS 89U.5	89U-8	L10	531	535	Waterhole Canyon Freight Improvement		Construct NB passing lane MP 534.5 - 535.5 Construct SB passing lane MP 531.5 - 533	M
CS 89U.6	89U-8	L9	534	547	Waterhole Canyon Safety Improvement	-	Install guardrail MP 537-538 Widen shoulders MP 537-547 Install high visibility striping and delineators, raised pavement markers, and rumble strips Install centerline rumble strips Install chevrons on curves MP 537.5-538	M
CS 89U.7	89U-9	L13	547	549	Page Intersection Safety Improvement	-	Construct single-lane roundabouts at Lake Powell Boulevard intersections MP 547.2 and 548.5 Install raised median MP 547.2 to 548.5	M

'-'indicates only one solution is being proposed and no options are being considered

Figure 9: Candidate Solutions



5.0 SOLUTION EVALUATION AND PRIORITIZATION

Candidate solutions are evaluated using the following steps: LCCA (where applicable), Performance Effectiveness Evaluation, Solution Risk Analysis, and Candidate Solution Prioritization. The methodology and approach to this evaluation are shown in **Figure 10** and described more fully below.

Life-Cycle Cost Analysis

All Pavement and Bridge candidate solutions have two options: rehabilitation/repair or reconstruction. These options are evaluated through an LCCA to determine the best approach for each location where a Pavement or Bridge solution is recommended. The LCCA can eliminate options from further consideration and identify which options should be carried forward for further evaluation.

When multiple independent candidate solutions are developed for Mobility, Safety, or Freight strategic investment areas, these candidate solution options advance directly to the Performance Effectiveness Evaluation without an LCCA.

Performance Effectiveness Evaluation

After completing the LCCA process, all remaining candidate solutions are evaluated based on their performance effectiveness. This process includes determining a Performance Effectiveness Score (PES) based on how much each solution impacts the existing performance and needs scores for each segment. This evaluation also includes a Performance Area Risk Analysis to help differentiate between similar solutions based on factors that are not directly addressed in the performance system.

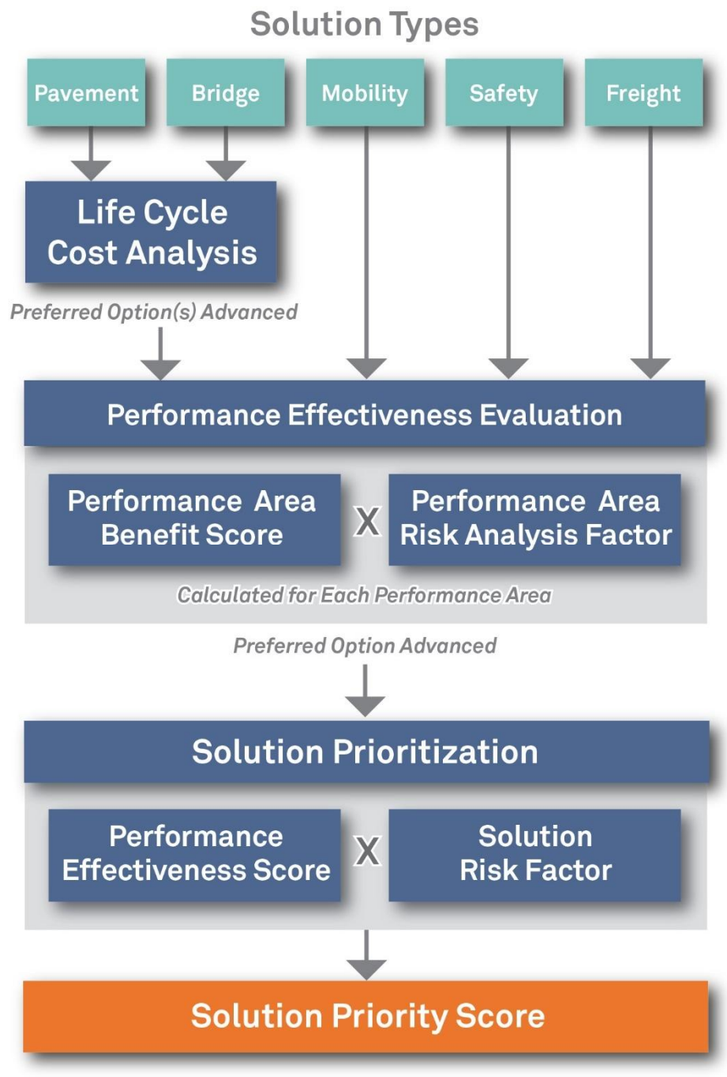
Solution Risk Analysis

All candidate solutions advanced through the Performance Effectiveness Evaluation are also evaluated through a Solution Risk Analysis process. A solution risk probability and consequence analysis is conducted to develop a solution-level risk weighting factor. This risk analysis is a numeric scoring system to help address the risk of not implementing a solution based on the likelihood and severity of performance failure.

Candidate Solution Prioritization

The PES, weighted risk factor, and segment average need score are combined to create a prioritization score. The candidate solutions are ranked by prioritization score from highest to lowest. The highest prioritization score indicates the candidate solution that is recommended as the highest priority. Solutions that address multiple performance areas tend to score higher in this process.

Figure 10: Candidate Solution Evaluation Process



5.1 Life-Cycle Cost Analysis

LCCA is conducted for any candidate solution that is developed as a result of a need in the Pavement or Bridge Performance Area. The intent of the LCCA is to determine which options warrant further investigation and eliminate options that would not be considered strategic.

LCCA is an economic analysis that compares cost streams over time and presents the results in a common measure, the present value of all future costs. The cost stream occurs over an analysis period that is long enough to provide a reasonably fair comparison among alternatives that may differ significantly in scale of improvement actions over shorter time periods. For both bridge and pavement LCCA, the costs are focused on agency (ADOT) costs for corrective actions to meet the objective of keeping the bridge or pavement serviceable over a long period of time.

LCCA is performed to provide a more complete holistic perspective on asset performance and agency costs over the life of an investment stream. This approach helps ADOT look beyond initial and short-term costs, which often dominate the considerations in transportation investment decision making and programming.

Bridge LCCA

For the bridge LCCA, three basic strategies are analyzed that differ in timing and scale of improvement actions to maintain the selected bridges, as described below:

- Bridge replacement (large upfront cost but small ongoing costs afterwards)
- Bridge rehabilitation until replacement (moderate upfront costs then small to moderate ongoing costs until replacement)
- On-going repairs until replacement (low upfront and ongoing costs until replacement)

The bridge LCCA model developed for the CPS reviews the characteristics of the candidate bridges including bridge ratings and deterioration rates to develop the three improvement strategies (full replacement, rehabilitation until replacement, and repair until replacement). Each strategy consists of a set of corrective actions that contribute to keeping the bridge serviceable over the analysis period. Cost and effect of these improvement actions on the bridge condition are essential parts of the model. Other considerations in the model include bridge age, elevation, pier height, length to span ratio, skew angle, and substandard characteristics such as shoulders and vehicle clearance. The following assumptions are included in the bridge LCCA model:

- The bridge LCCA only addresses the structural condition of the bridge and does not address other issues or costs
- The bridge will require replacement at the end of its 75-year service life regardless of current condition
- The bridge elevation, pier height, skew angle, and length to span ratio can affect the replacement and rehabilitation costs
- The current and historical ratings are used to estimate a rate of deterioration for each candidate bridge
- Following bridge replacement, repairs will be needed every 20 years
- Different bridge repair and rehabilitation strategies have different costs, expected service life, and benefit to the bridge rating
- The net present value of future costs is discounted at 3% and all dollar amounts are in 2015 dollars
- If the LCCA evaluation recommends rehabilitation or repair, the solution is not considered strategic and the rehabilitation or repair will be addressed by normal programming processes
- Because this LCCA is conducted at a planning level, and due to the variabilities in costs and improvement strategies, the LCCA net present value results that are within 15% should be considered equally; in such a case, the solution should be carried forward as a strategic replacement project – more detailed scoping will confirm if replacement or rehabilitation is needed

Based on the candidate solutions presented in **Table 5**, LCCA was not conducted for any bridges on the US 89 Corridor. A summary of this analysis is shown in **Table 6**. Additional information regarding the bridge LCCA is included in **Appendix E**.

Pavement LCCA

The LCCA approach to pavement is very similar to the process used for bridges. For the pavement LCCA, three basic strategies are analyzed that differ in timing and scale of improvement actions to maintain the selected pavement, as described below:

- Pavement replacement (large upfront cost but small ongoing costs afterwards – could be replacement with asphalt or concrete pavement)
- Pavement major rehabilitation until replacement (moderate upfront costs then small to moderate ongoing costs until replacement)
- Pavement minor rehabilitation until replacement (low upfront and ongoing costs until replacement)

The pavement LCCA model developed for the CPS reviews the characteristics of the candidate paving locations including the historical rehabilitation frequency to develop potential improvement strategies (full replacement, major rehabilitation until replacement, and minor rehabilitation until replacement, for either concrete or asphalt, as applicable). Each strategy consists of a set of corrective actions that contribute to keeping the pavement serviceable over the analysis period. The following assumptions are included in the pavement LCCA model:

- The pavement LCCA only addresses the condition of the pavement and does not address other issues or costs
- The historical pavement rehabilitation frequencies at each location are used to estimate future rehabilitation frequencies
- Different pavement replacement and rehabilitation strategies have different costs and expected service life

- The net present value of future costs is discounted at 3% and all dollar amounts are in 2015 dollars
- If the LCCA evaluation recommends rehabilitation or repair, the solution is not considered strategic and the rehabilitation will be addressed by normal programming processes
- Because this LCCA is conducted at a planning level, and due to the variabilities in costs and improvement strategies, the LCCA net present value results that are within 15% should be considered equally; in such a case, the solution should be carried forward as a strategic replacement project – more detailed scoping will confirm if replacement or rehabilitation is needed

Based on the candidate solutions presented in **Table 5**, LCCA was conducted for one pavement solution on the US 89 Corridor. A summary of this analysis is shown in **Table 7.** Additional information regarding the pavement LCCA is included in **Appendix E.**

As shown in **Table 6** and **Table 7**, the following conclusions were determined based on the LCCA:

- Rehabilitation or repair was determined to be the most effective approach for CS89U.4 (MP 470 - 475). Therefore, it is assumed that the identified need will be addressed by normal programming processes and this candidate solution will be dropped from further consideration.

Table 6: Bridge Life-Cycle Cost Analysis Results

Candidate Solution	Present Value at 3% Discount Rate ($)			Ratio of Present Value Compared to Lowest Present Value			Other Needs	Results
	Replace	Rehab	Repair	Replace	Rehab	Repair		
No LCCA conducted for any bridges on the US 89 Corridor.								

Table 7: Pavement Life-Cycle Cost Analysis Results

Candidate Solution	Present Value at 3% Discount Rate ($)				Ratio of Present Value Compared to Lowest Present Value				Other Needs	Results
	Concrete Reconstruction	Asphalt Reconstruction	Asphalt Medium Rehabilitation	Asphalt Light Rehabilitation	Concrete Reconstruction	Asphalt Reconstruction	Asphalt Medium Rehabilitation	Asphalt Light Rehabilitation		
North Cameron Pavement (CS 89U.4) (MP 470-475)	$21,427,000	$22,450,000	$17,549,000	$19,902,000	1.22	1.28	1.00	1.13	Y	Not strategic as a stand-along solution as rehabilitation appears be to the most effective approach.

5.2 Performance Effectiveness Evaluation

The results of the Performance Effectiveness Evaluation are combined with the results of a Performance Area Risk Analysis to determine a Performance Effectiveness Score (PES). The objectives of the Performance Effectiveness Evaluation include:

- Measure the benefit to the performance system versus the cost of the solution
- Include risk factors to help differentiate between similar solutions
- Apply to each performance area that is affected by the candidate solution
- Account for emphasis areas identified for the corridor

The Performance Effectiveness Evaluation includes the following steps:

- Estimate the post-solution performance for each of the five performance areas (Pavement, Bridge, Mobility, Safety, and Freight)
- Use the post-solution performance scores to calculate a post-solution level of need for each of the five performance areas
- Compare the pre-solution level of need to the post-solution level of need to determine the reduction in level of need (potential solution benefit) for each of the five performance areas
- Calculate performance area risk weighting factors for each of the five performance areas
- Use the reduction in level of need (benefit) and risk weighting factors to calculate the PES

Post-Solution Performance Estimation

For each performance area, a slightly different approach is used to estimate the post-solution performance. This process is based on the following assumptions:

- Pavement:
  - The IRI rating would decrease (to 30 for replacement or 45 for rehabilitation)
  - The Cracking rating would decrease (to 0 for replacement or rehabilitation)
- Bridge:
  - The structural ratings would increase (+1 for repair, +2 for rehabilitation, or increase to 8 for replacement)
  - The Sufficiency Rating would increase (+10 for repair, +20 for rehabilitation, or increase to 98 for replacement)
- Mobility:
  - Additional lanes would increase the capacity and therefore affect the Mobility Index and associated secondary measures
  - Other improvements (e.g., ramp metering, parallel ramps, variable speed limits) would also increase the capacity (to a lesser extent than additional lanes) and therefore would affect the Mobility Index and associated secondary measures
  - Changes in the Mobility Index (due to increased capacity) would have a direct effect on the TTI secondary measure
  - Changes in the Mobility Index (due to increased capacity) and Safety Index (due to crash reductions) would have a direct effect on the PTI secondary measure
  - Changes in the Safety Index (due to crash reductions) would have a direct effect on the Closure Extent secondary measure
- Safety:
  - Crash modification factors were developed that would be applied to estimate the reduction in crashes (for additional information see **Appendix F**)
- Freight:
  - Changes in the Mobility Index (due to increased capacity) and Safety Index (due to crash reductions) would have a direct effect on the Freight Index and the TPTI secondary measure
  - Changes in the Mobility Index (due to increased capacity) would have a direct effect on the TTTI secondary measure
  - Changes in the Safety Index (due to crash reductions) would have a direct effect on the Closure Duration secondary measure

Performance Area Risk Analysis

The Performance Area Risk Analysis is intended to develop a numeric risk weighting factor for each of the five performance areas (Pavement, Bridge, Mobility, Safety, and Freight). This risk analysis addresses other considerations for each performance area that are not directly included in the performance system. A risk weighting factor is calculated for each candidate solution based on the specific characteristics at the solution location. For example, the Pavement Risk Factor is based on factors such as the elevation, daily traffic volumes, and amount of truck traffic. Additional information regarding the Performance Area Risk Factors is included in **Appendix G**.

Following the calculation of the reduction in level of need (benefit) and the Performance Area Risk Factors, these values are used to calculate the PES. In addition, the reduction in level of Need in each emphasis area is also included in the PES.

Net Present Value Factor

The benefit (reduction in need) is measured as a one-time benefit. However, different types of solutions will have varying service lives during which the benefits will be obtained. For example, a preservation solution would likely have a shorter stream of benefits over time when compared to a modernization or expansion solution. To address the varying lengths of benefit streams, each solution is classified as a 10-year, 20-year, 30-year, or 75-year benefit stream, or the net present value (NPV) factor (F_{NPV}). A 3% discount rate is used to calculate F_{NPV} for each classification of solution. The service lives and respective factors are described below:

- A 10-year service life is generally reflective of preservation solutions such as pavement and bridge preservation; these solutions would likely have a 10-year stream of benefits; for these solutions, a F_{NPV} of 8.8 is used in the PES calculation
- A 20-year service life is generally reflective of modernization solutions that do not include new infrastructure; these solutions would likely have a 20-year stream of benefits; for these solutions, a F_{NPV} of 15.3 is used in the PES calculation

- A 30-year service life is generally reflective of expansion solutions or modernization solutions that include new infrastructure; these solutions would likely have a 30-year stream of benefits; for these solutions, a F_{NPV} of 20.2 is used in the PES calculation
- A 75-year service life is used for bridge replacement solutions; these solutions would likely have a 75-year stream of benefits; for these solutions, a F_{NPV} of 30.6 is used in the PES calculation

Vehicle-Miles Travelled Factor

Another factor in assessing benefits is the number of travelers who would benefit from the implementation of the candidate solution. This factor varies between candidate solutions depending on the length of the solution and the magnitude of daily traffic volumes. Multiplying the solution length by the daily traffic volume results in vehicle-miles travelled (VMT), which provides a measure of the amount of traffic exposure that would receive the benefit of the proposed solution. The VMT is converted to a VMT factor (known as F_{VMT}), which is on a scale between 0 and 5, using the equation below:

$$F_{VMT} = 5 - (5 \times e^{VMT \times -0.0000139})$$

Performance Effectiveness Score

The PES is calculated using the following equation:

PES = (Sum of all Risk Factored Benefit Scores + Sum of all Risk Factored Emphasis Area Scores) / Cost) x F_{VMT} x F_{NPV}

Where:

Risk Factored Benefit Score = Reduction in Segment-Level Need (benefit) x Performance Area Risk Weighting Factor (calculated for each performance area)

Risk Factored Emphasis Area Score = Reduction in Corridor-Level Need x Performance Area Risk Factors x Emphasis Area Factor (calculated for each emphasis area)

*Cost = estimated cost of candidate solution in millions of dollars (see **Appendix H**)*

F_{VMT} = Factor between 0 and 5 to account for VMT at location of candidate solution based on existing (2014) daily volume and length of solution

F_{NPV} = Factor (ranging from 8.8 to 30.6 as previously described) to address anticipated longevity of service life (and duration of benefits) for each candidate solution

The resulting PES values are shown in **Table 8**. Additional information regarding the calculation of the PES is contained in **Appendix I**.

For candidate solutions with multiple options to address Mobility, Safety, or Freight needs, the PES should be compared to help identify the best performing option. If one option clearly performs better than the others (more than twice the PES value and a difference in magnitude of at least 20 points) the lower scoring options can be eliminated from further consideration. If multiple options have similar PES values, or there are other factors not accounted for in the performance system that could significantly influence the ultimate selection of an option (e.g., potential environmental concerns, potential adverse economic impacts), those options should all be advanced to the prioritization process. On the US 89 Corridor, the following candidate solutions have options to address Mobility, Safety, or Freight needs:

- CS89U.3 (A and B) – North Cameron Safety Improvements

Based on a review of the PES values for the candidate solutions with options, CS 89U.3A has been removed from consideration and did not advance to the prioritization process due to a large difference in PES values between Options A and B. As shown in **Table 8**, the performance effectiveness of CS 89U.3A (PES = 10.1) is considerably lower than CS 89U.3A (PES = 40.3).

As was previously mentioned, rehabilitation was determined to be the most effective approach for the candidate solution listed below that was subjected to LCCA so this candidate solution was dropped from further consideration. No PES value was calculated for this solution, as shown in **Table 8**.

- North Cameron Pavement (CS 89U.4)

Table 8: Performance Effectiveness Scores

Candidate Solution #	Segment #	Candidate Solution Name	Milepost Location	Estimated Cost* ($ million)	Risk Factored Benefit Score					Risk Factored Emphasis Area Scores			Total Factored Benefit Score	F^{VMT}	F^{NPV}	Performance Effectiveness Score
					Pavement	Bridge	Safety	Mobility	Freight	Safety	Mobility	Pavement				
CS 89U.1	89U-2	Sunset Crater Safety Improvement	428-432	0.54	0.000	0.000	0.942	0.016	0.950	0.014	0.000	0.000	1.922	1.42	15.3	77.5
CS 89U.2	89U-2	Antelope Hills Safety Improvement	436-440	5.91	0.000	0.000	4.177	0.026	1.451	0.050	0.000	0.000	5.704	1.42	15.3	21.0
CS 89U.3-A	89U-5	North Cameron Safety Improvement – Option A	467-475	59.68	0.277	0.000	8.053	1.754	0.159	0.091	0.264	0.140	10.737	2.79	20.2	10.1[1]
CS 89U.3-B	89U-5	North Cameron Safety Improvement – Option B	467-475	8.45	0.000	0.000	7.815	0.042	0.038	0.091	0.000	0.000	7.986	2.79	15.3	40.3
CS 89U.5	89U-8	Waterhole Canyon Freight Improvement	531-535	9.32	0.000	0.000	8.732	4.012	12.176	0.148	0.035	0.000	25.102	0.57	20.2	31.1
CS 89U.6	89U-8	Waterhole Canyon Safety Improvement	534-547	11.854	0.000	0.000	7.574	3.333	6.560	0.083	0.000	0.000	17.551	1.92	15.3	43.5
CS 89U.7	89U-9	Page Intersection Safety Improvement	547-549	11.43	0.000	0.000	33.772	0.192	0.862	0.132	0.005	0.000	34.963	0.36	20.2	22.3

[1] *Not carried forward for Prioritization*

5.3 Solution Risk Analysis

Following the calculation of the PES, an additional step is taken to develop the prioritized list of solutions. A solution risk probability and consequence analysis is conducted to develop a solution-level risk weighting factor. This risk analysis is a numeric scoring system to help address the risk of not implementing a solution based on the likelihood and severity of performance failure. **Figure 11** shows the risk matrix used to develop the risk weighting factors.

Figure 113: Risk Matrix

		Severity/Consequence				
		Insignificant	Minor	Significant	Major	Catastrophic
Frequency/Likelihood	Very Rare	Low	Low	Low	Moderate	Major
	Rare	Low	Low	Moderate	Major	Major
	Seldom	Low	Moderate	Moderate	Major	Severe
	Common	Moderate	Moderate	Major	Severe	Severe
	Frequent	Moderate	Major	Severe	Severe	Severe

Using the risk matrix in **Figure 11**, numeric values were assigned to each category of frequency and severity. The higher the risk, the higher the numeric factor assigned. The risk weight for each area of the matrix was calculated by multiplying the severity factor times the frequency factor. These numeric factors are shown in **Figure 12**.

Figure 12: Numeric Risk Matrix

			Severity/Consequence				
			Insignificant	Minor	Significant	Major	Catastrophic
		Weight	1.00	1.10	1.20	1.30	1.40
Frequency/Likelihood	Very Rare	1.00	1.00	1.10	1.20	1.30	1.40
	Rare	1.10	1.10	1.21	1.32	1.43	1.54
	Seldom	1.20	1.20	1.32	1.44	1.56	1.68
	Common	1.30	1.30	1.43	1.56	1.69	1.82
	Frequent	1.40	1.40	1.54	1.68	1.82	1.96

Using the values in **Figure 12**, risk weighting factors were calculated for each of the four risk categories (low, moderate, major, and severe). These values are simply the average of the values in **Figure 12** that fall within each category. The resulting average risk weighting factors are:

Low	Moderate	Major	Severe
1.14	1.36	1.51	1.78

The risk weighting factors listed above are assigned to the five performance areas as follows:

- Safety = 1.78
  - The Safety performance area quantifies the likelihood of fatal or incapacitating injury crashes; therefore, it is assigned the Severe (1.78) risk weighting factor
- Bridge = 1.51
  - The Bridge performance area focuses on the structural adequacy of bridges; a bridge failure may result in crashes or traffic being detoured for long periods of time resulting in significant travel time increases; therefore, it is assigned the Major (1.51) risk weighting factor
- Mobility and Freight = 1.36
  - The Mobility and Freight performance areas focus on capacity and congestion; failure in either of these performance areas would result in increased travel times but would not have significant effect on safety (crashes) that would not already be addressed in the Safety performance area; therefore, they are assigned the Moderate (1.36) risk weighing factor
- Pavement = 1.14
  - The Pavement performance area focuses on the ride quality of the pavement; failure in this performance area would likely be a spot location that would not dramatically affect drivers beyond what is already captured in the Safety performance area; therefore, it is assigned the Low (1.14) risk weighting factor

The benefit in each performance area is calculated for each candidate solution as part of the Performance Effectiveness Evaluation. Using this information on benefits and the risk factors listed above, a weighted (based on benefit) solution-level numeric risk factor is calculated for each candidate solution. For example, a solution that has 50% of its benefit in Safety and 50% of its benefit in Mobility has a weighted risk factor of 1.57 (0.50 x 1.36 + 0.50 x 1.78 = 1.57).

5.4 Candidate Solution Prioritization

The PES, weighted risk factor, and segment average need score are combined to create a prioritization score as follows:

Prioritization Score = PES x Weighted Risk Factor x Segment Average Need Score

Where:

*PES = Performance Effectiveness Score as shown in **Table 8***

Weighted Risk Factor = Weighted factor to address risk of not implementing a solution based on the likelihood and severity of the performance failure

*Segment Average Need Score = Segment level need score as shown in **Table 3***

The candidate solutions are prioritized based on the calculation above as shown in **Table 9**. The highest prioritization score indicates the candidate solution that is recommended as the highest priority. Solutions that address multiple performance areas tend to score higher in this process. The prioritized list of candidate solutions is provided in the subsequent section. See **Appendix J** for additional information on the prioritization process

Table 9: Prioritization Scores

Candidate Solution #	Segment #	Option	Solution Name	Milepost Location	Estimated Cost ($ million)	Performance Effectiveness Score	**Weighted Risk Factor**	Segment Average Need Score	Prioritization Score	Percentage by which Solution Reduces Performance Area Segment Needs				
										Pavement	Bridge	Safety	Mobility	Freight
CS 89U.1	89U-2	-	Sunset Crater Safety Improvement	428-432	0.54	77.5	1.569	1.15	140	0.0%	0.0%	18.9%	0.8%	3.6%
CS 89U.2	89U-2	-	Antelope Hills Safety Improvement	436-440	5.91	21.0	1.671	1.15	40	0.0%	0.0%	57.6%	1.3%	5.6%
CS 89U.3	89U-5	B	North Cameron Safety Improvement	467-475	8.45	40.3	1.776	1.31	94	0.0%	0.0%	81.9%	0.7%	3.6%
CS 89U.5	89U-8	-	Waterhole Canyon Freight Improvement	531-535	9.32	31.1	1.509	1.62	76	0.0%	0.0%	85.0%	14.5%	0.5%
CS 89U.6	89U-8	-	Waterhole Canyon Safety Improvement	534-547	11.854	43.5	1.543	1.62	109	0.0%	0.0%	77.8%	11.1%	0.3%
CS 89U.7	89U-9	-	Page Intersection Safety Improvement	547-549	11.43	22.3	1.767	1.69	67	0.0%	0.0%	92.6%	9.1%	20.5%

6.0 SUMMARY OF CORRIDOR RECOMMENDATIONS

6.1 Prioritized Candidate Solution Recommendations

Table 24 and **Figure 13** show the ranked prioritized candidate solutions recommended for the US 89 Corridor. Implementation of these solutions is anticipated to improve performance of the US 89 Corridor. The following observations were noted about the prioritized solutions:

- Most of the anticipated improvements in performance are in the Safety performance area
- The highest ranking solutions tended to have overlapping benefits in the Mobility, Safety, and Freight performance areas
- The highest priority solutions address needs in the Sunset Crater (MP 428-432) and Waterhole Canyon areas (MP 534-547).

6.2 Other Corridor Recommendations

As part of the investigation of strategic investment areas and candidate solutions, other corridor recommendations can also be identified. These recommendations could include modifications to the existing Statewide Construction Program, areas for further study, or other corridor-specific recommendations that are not related to construction or policy. The list below identifies other corridor recommendations for the US 89 Corridor:

- When recommending future projects along the US 89 Corridor, review historical ratings and levels of investment. According to data used for this study, the following pavement and bridge locations have exhibited high historical investment (pavement) or rating fluctuation (bridge) issues:
  - Pavement MP 465-481
- Conduct an access management study within the City of Page to help preserve and manage access to/from US 89

6.3 Policy and Initiative Recommendations

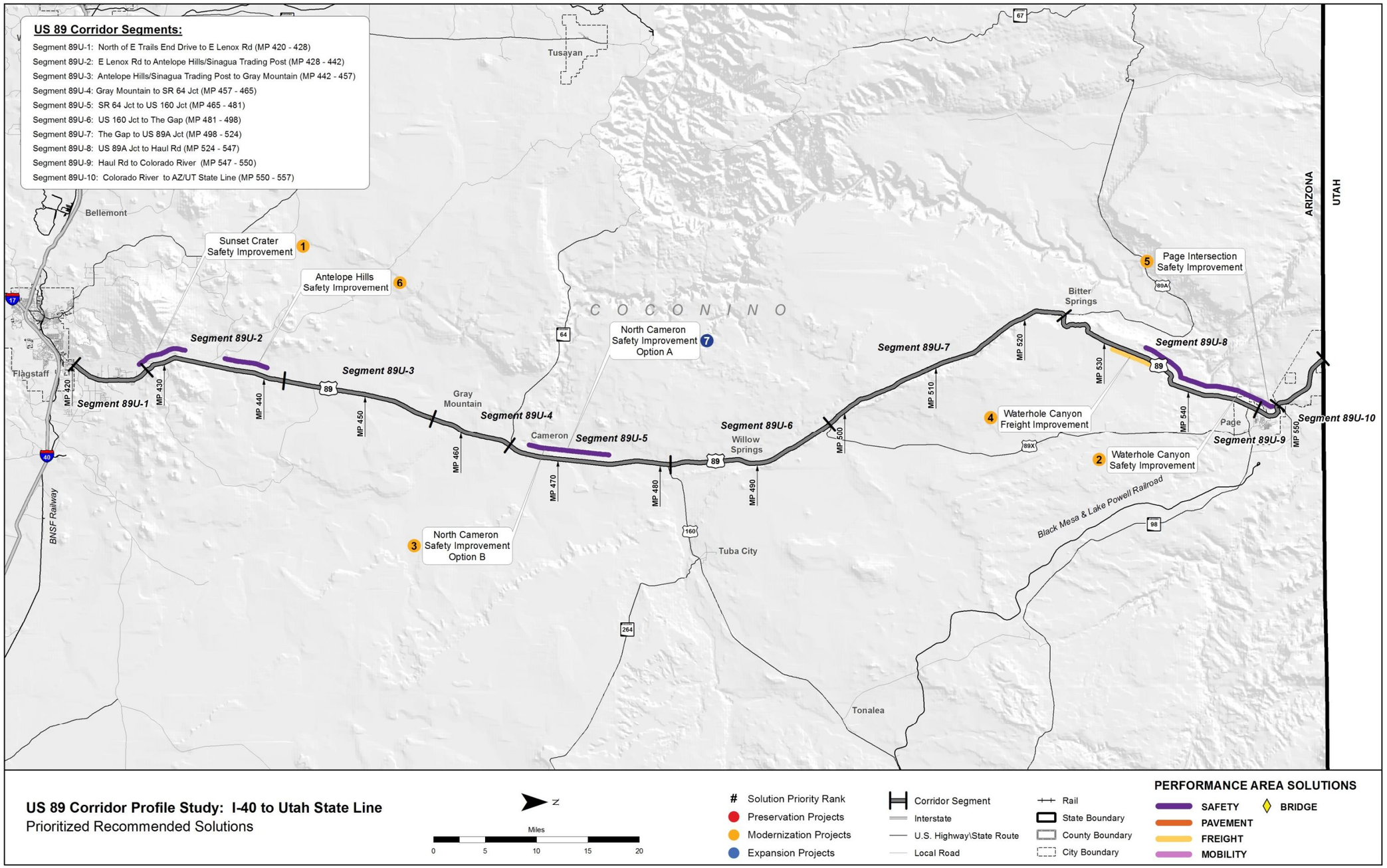
In addition to location-specific needs, general corridor and system-wide needs have also been identified through the CPS process. While these needs are more overarching and cannot be individually evaluated through this process, it is important to document them. A list of recommended policies and initiatives was developed for consideration when programming future projects not only on US 89, but across the entire state highway system where the conditions are applicable. The following list, which is in no particular order of priority, was derived from the Round 1, Round 2, and Round 3 CPS:

- Install Intelligent Transportation System (ITS) conduit with all new infrastructure projects
- Prepare strategic plans for Closed Circuit Television (CCTV) camera and Road Weather Information System (RWIS) locations statewide
- Leverage power and communication at existing weigh-in-motion (WIM), dynamic message signs (DMS), and call box locations to expand ITS applications across the state
- Consider solar power for lighting and ITS where applicable
- Investigate ice formation prediction technology where applicable
- Conduct highway safety manual evaluation for all future programmed projects
- Develop infrastructure maintenance and preservation plans (including schedule and funding) for all pavement and bridge infrastructure replacement or expansion projects
- Develop standardized bridge maintenance procedures so districts can do routine maintenance work
- Review historical ratings and level of previous investment during scoping of pavement and bridge projects. In pavement locations that warrant further investigation, conduct subsurface investigations during project scoping to determine if full replacement is warranted
- For pavement rehabilitation projects, enhance the amount/level of geotechnical investigations to address issues specific to the varying conditions along the project
- Expand programmed and future pavement projects as necessary to include shoulders
- Expand median cable barrier guidelines to account for safety performance
- Install CCTV cameras with all DMS
- In locations with limited communications, use CCTV cameras to provide still images rather than streaming video
- Develop statewide program for pavement replacement
- Install additional continuous permanent count stations along strategic corridors to enhance traffic count data
- When reconstruction or rehabilitation activities will affect existing bridge vertical clearance, the dimension of the new bridge vertical clearance should be a minimum of 16.25 feet where feasible
- All new or reconstructed roadway/shoulder edges adjacent to an unpaved surface should be constructed with a Safety Edge
- Collision data on tribal lands may be incomplete or inconsistent; additional coordination for data on tribal lands is required to ensure adequate reflection of safety issues
- Expand data collection devices statewide to measure freight delay
- Evaluate and accommodate potential changes in freight and goods movement trends that may result from improvements and expansions to the state roadway network

Table 10: Prioritized Recommended Solutions

Rank	Candidate Solution #	Solution Name and Location	Scope	Estimated Cost (in millions)	Investment Category [P] Preservation [M] Modernization [E] Expansion	Prioritization Score
1	CS 89U.1	Sunset Crater Safety Improvement (MP 428 – 432)	Install high visibility striping and delineators, raised pavement markers, and rumble strips Install chevrons on curves	$0.54	M	**140**
2	CS 89U.6	Waterhole Canyon Safety Improvement (MP 534 – 547)	Install guardrail MP 537-538 Widen shoulders MP 537-547 Install high visibility striping and delineators, raised pavement markers, and rumble strips Install centerline rumble strips Install chevrons on curves MP 537.5-538	$11.854	M	**109**
3	CS 89U.3	North Cameron Safety Improvement (MP 467 -475)	Install high visibility striping and delineators, raised pavement markers, and rumble strips Construct SB passing lane MP 467.5 – 468.5 Widen shoulders MP 467–468, MP 469–470, MP 471-472, MP 474-475	$8.45	M	**94**
4	CS 89U.5	Waterhole Canyon Freight Improvement (MP 531 – 535)	Construct NB passing lane MP 534.5 - 535.5 Construct SB passing lane MP 531.5 - 533	$9.32	M	**76**
5	CS 89U.7	Page Intersection Safety Improvement (MP 547 – 549)	Construct single-lane roundabouts at Lake Powell Boulevard intersections MP 547.2 and 548.5 Install raised median MP 547.2 to 548.5	$11.43	M	**67**
6	CS 89U.2	Antelope Hills Safety Improvement (MP 436 – 440)	Install high visibility striping and delineators, raised pavement markers, and rumble strips Install chevrons on curves Install roadway lighting	$5.91	M	**40**

Figure 134: Prioritized Recommended Solutions



6.4 Next Steps

The candidate solutions recommended in this study are not intended to be a substitute or replacement for traditional ADOT project development processes where various ADOT technical groups and districts develop candidate projects for consideration in the performance-based programming in the P2P process. Rather, these candidate solutions are intended to complement ADOT's traditional project development processes through a performance-based process to address needs in one or more of the five performance areas of Pavement, Bridge, Mobility, Safety, and Freight. Candidate solutions developed for the US 89 Corridor will be considered along with other candidate projects in the ADOT statewide programming process.

It is important to note that the candidate solutions are intended to represent strategic solutions to address existing performance needs related to the Pavement, Bridge, Mobility, Safety, and Freight performance areas. Therefore, the strategic solutions are not intended to preclude recommendations related to the ultimate vision for the corridor that may have been defined in the context of prior planning studies and/or design concept reports. Recommendations from such studies are still relevant to addressing the ultimate corridor objectives.

Upon completion of all four CPS rounds, the results will be incorporated into a summary document comparing all corridors that is expected to provide a performance-based review of statewide needs and candidate solutions.

Appendix E: Life-Cycle Cost Analysis

Pavement Life-Cycle Cost Analysis Worksheet

Project Details	
Project title	Life-Cycle Cost Analysis for US 89 Corridor Profile Study
Route	US 89
Milepost begin	470
Milepost end	475

Existing Roadway Characteristics			
Surface type (Asphalt or Concrete)	=	Asphalt	<<Select from Pull-down List>>
# of directions of travel (1 = one-way; 2 = two-way)	=	2	
# of lanes (in one direction)	=	1	
Width of typical lane (ft)	=	12	
Left shoulder width (ft)	=	0	
Right shoulder width (ft)	=	6	
Total roadway analysis segment length (centerline miles)	=	5	
Current year	=	2016	
Elevation (> 4,000 ft or < 4,000 ft)?	=	> 4,000 ft	<<Select from Pull-down List>>
Roadway width (ft) [each direction lanes & shoulders]	=	18	
Total lane-miles [total traffic direction lanes & shoulders]	=	15.0	
Total square feet [total traffic direction lanes & shoulders]	=	950,400	
Total square yards [total traffic direction lanes & shoulders]	=	105,600	

LCCA Parameters		
Analysis period (years)	=	40
Year of net present value	=	2017
First year of improvements	=	2021
Discount rate (%) - low	=	3%
Discount rate (%) - high	=	7%

Design Alternatives (DA)

	Characteristics		Pavement Material Cost ($)		
Treatment Type	*Pavement Thickness*	*Typical Service Life (years)*	*Lane-miles*	*Square Feet*	*Square Yards*
Concrete Reconstruction	8"-12"	26-30	$350,000	$5.5	$50
Asphalt Reconstruction	8"-12"	22-26	$280,000	$4.4	$40
Concrete Medium Rehab	1"-3"	20-24	$75,000	$1.2	$11
Concrete Light Rehab	<1"	14-18	$50,000	$0.8	$7
Asphalt Medium Rehab	3"-8"	16-20	$105,000	$1.7	$15
Asphalt Light Rehab	<3"	10-14	$70,000	$1.1	$10

Reconstruction: Other Materials Cost Factor: 1.60

Rehab: Other Materials Cost Factor: 1.20

Total Cost Factor (e.g., includes design, mobilization, traffic control, contingency, etc.): 2.44

			Total Unit Cost ($) [includes material costs and indirect costs]			Total Bi-Directional Cost ($)
Treatment Type	Pavement Thickness	Typical Service Life (years)	Lane-miles	Square Feet	Square Yards	Total Cost
Concrete Reconstruction	8"-12"	26-30	$1,366,400	$21.6	$194	$20,496,000
Asphalt Reconstruction	8"-12"	22-26	$1,093,120	$17.3	$155	$16,396,800
Concrete Medium Rehab	1"-3"	20-24	$219,600	$3.5	$31	$3,294,000
Concrete Light Rehab	<1"	14-18	$146,400	$2.3	$21	$2,196,000
Asphalt Medium Rehab	3"-8"	16-20	$307,440	$4.9	$44	$4,611,600
Asphalt Light Rehab	<3"	10-14	$204,960	$3.2	$29	$3,074,400

Pavement Improvement Project History

US 89 MP 470 - MP 475

Year	Project Number	Tracs No.	Direction of Improvement	Treatment Type	Improvement Description	Thickness (inches)	Beg. MP	End MP	Length (miles)
1962	PMS01144		Both	Asphalt Reconstruction	New Construction	12	467	472	5
1961	PMS01143		Both	Asphalt Reconstruction	New Construction	15	472	476	4
1980	PMS00085		Both	Asphalt Medium Rehab	RE 3", 4" AC	4	470	473	3
1983	PMS 00695		Both	Asphalt Medium Rehab	RE 3", 4" AC	4	473	478	5
2000	H421401C		Both	Asphalt Medium Rehab	3" AC	3	470	476	6
									0
									0
									0
									0
									0
									0

Interval between Improvements in Years	Treatment Type Options	Estimated Historical Interval Value between Improvements in Years
18	Concrete Reconstruction	
17	Asphalt Reconstruction	
0	Concrete Medium Rehab	
0	Concrete Light Rehab	
0	Asphalt Medium Rehab	17.5
0	Asphalt Light Rehab	
0		
0		
0		

Design Alternative # 1 - Concrete Reconstruction

US 89 MP 470 - MP 475

Enter Name of Design Alternative

Number of Years	Year	Concrete Reconstruction	Agency Cost ($)	Net Present Value @ 3%	Net Present Value @ 7%
0	2016	None	$0	$0	$0
1	2017	None	$0	$0	$0
2	2018	None	$0	$0	$0
3	2019	None	$0	$0	$0
4	2020	None	$0	$0	$0
5	2021	Concrete Reconstruction	$20,496,000	$18,210,431	$15,636,300
6	2022	None	$0	$0	$0
7	2023	None	$0	$0	$0
8	2024	None	$0	$0	$0
9	2025	None	$0	$0	$0
10	2026	None	$0	$0	$0
11	2027	None	$0	$0	$0
12	2028	None	$0	$0	$0
13	2029	None	$0	$0	$0
14	2030	None	$0	$0	$0
15	2031	None	$0	$0	$0
16	2032	None	$0	$0	$0
17	2033	None	$0	$0	$0
18	2034	None	$0	$0	$0
19	2035	Concrete Light Rehab	$2,196,000	$1,289,919	$649,717
20	2036	None	$0	$0	$0
21	2037	None	$0	$0	$0
22	2038	None	$0	$0	$0
23	2039	None	$0	$0	$0
24	2040	None	$0	$0	$0
25	2041	None	$0	$0	$0
26	2042	None	$0	$0	$0
27	2043	Concrete Medium Rehab	$3,294,000	$1,527,410	$567,212
28	2044	None	$0	$0	$0
29	2045	None	$0	$0	$0
30	2046	None	$0	$0	$0
31	2047	None	$0	$0	$0
32	2048	None	$0	$0	$0
33	2049	None	$0	$0	$0
34	2050	None	$0	$0	$0
35	2051	None	$0	$0	$0
36	2052	None	$0	$0	$0
37	2053	None	$0	$0	$0
38	2054	Concrete Light Rehab	$2,196,000	$735,623	$179,652
39	2055	None	$0	$0	$0
40	2056	None	$0	$0	$0
41	2057	None	$0	$0	$0
42	2058	None	$0	$0	$0
43	2059	None	$0	$0	$0
44	2060	None	$0	$0	$0
45	2061	None	$0	$0	$0
Pick Last Used DA treatment type to calculate Remaining Service Life ››		Concrete Light Rehab	$1,235,250	$336,447	$62,932
Enter Year of Last Used DA Improvement ››		2054	Remaining Service Life Cost ^^		

	Net Present Value ($) @ 3%	Net Present Value ($) @ 7%
NET PRESENT VALUE	$21,426,935	$16,969,950
AGENCY COST	$26,946,750	

Design Alternative # 2 - Asphalt Reconstruction

US 89 MP 470 - MP 475

Enter Name of Design Alternative

Number of Years	Year	Asphalt Reconstruction	Agency Cost ($)	Net Present Value @ 3%	Net Present Value @ 7%
0	2016	None	$0	$0	$0
1	2017	None	$0	$0	$0
2	2018	None	$0	$0	$0
3	2019	None	$0	$0	$0
4	2020	None	$0	$0	$0
5	2021	Asphalt Reconstruction	$16,396,800	$14,568,344	$12,509,040
6	2022	None	$0	$0	$0
7	2023	None	$0	$0	$0
8	2024	None	$0	$0	$0
9	2025	None	$0	$0	$0
10	2026	None	$0	$0	$0
11	2027	None	$0	$0	$0
12	2028	None	$0	$0	$0
13	2029	None	$0	$0	$0
14	2030	None	$0	$0	$0
15	2031	None	$0	$0	$0
16	2032	None	$0	$0	$0
17	2033	Asphalt Light Rehab	$3,074,400	$1,915,864	$1,041,406
18	2034	None	$0	$0	$0
19	2035	None	$0	$0	$0
20	2036	None	$0	$0	$0
21	2037	None	$0	$0	$0
22	2038	None	$0	$0	$0
23	2039	Asphalt Medium Rehab	$4,611,600	$2,406,759	$1,040,899
24	2040	None	$0	$0	$0
25	2041	None	$0	$0	$0
26	2042	None	$0	$0	$0
27	2043	None	$0	$0	$0
28	2044	None	$0	$0	$0
29	2045	None	$0	$0	$0
30	2046	None	$0	$0	$0
31	2047	None	$0	$0	$0
32	2048	Asphalt Light Rehab	$3,074,400	$1,229,720	$377,453
33	2049	None	$0	$0	$0
34	2050	None	$0	$0	$0
35	2051	None	$0	$0	$0
36	2052	None	$0	$0	$0
37	2053	None	$0	$0	$0
38	2054	Asphalt Reconstruction	$16,396,800	$5,492,648	$1,341,403
39	2055	None	$0	$0	$0
40	2056	None	$0	$0	$0
41	2057	None	$0	$0	$0
42	2058	None	$0	$0	$0
43	2059	None	$0	$0	$0
44	2060	None	$0	$0	$0
45	2061	None	$0	$0	$0
Pick Last Used DA treatment type to calculate Remaining Service Life ››		Asphalt Reconstruction	$11,614,400	$3,163,435	$591,712
Enter Year of Last Used DA Improvement ››		2054	Remaining Service Life Cost ^^		

	Net Present Value ($) @ 3%	Net Present Value ($) @ 7%
NET PRESENT VALUE	$22,449,902	$15,718,489
AGENCY COST	$31,939,600	

Design Alternative # 3 - Asphalt Medium Rehab

US 89 MP 470 - MP 475

Enter Name of Design Alternative

Number of Years	Year	Asphalt Medium Rehab Focus	Agency Cost ($)	Net Present Value @ 3%	Net Present Value @ 7%
0	2016	None	$0	$0	$0
1	2017	None	$0	$0	$0
2	2018	None	$0	$0	$0
3	2019	None	$0	$0	$0
4	2020	None	$0	$0	$0
5	2021	Asphalt Medium Rehab	$4,611,600	$4,097,347	$3,518,168
6	2022	None	$0	$0	$0
7	2023	None	$0	$0	$0
8	2024	None	$0	$0	$0
9	2025	None	$0	$0	$0
10	2026	None	$0	$0	$0
11	2027	None	$0	$0	$0
12	2028	None	$0	$0	$0
13	2029	None	$0	$0	$0
14	2030	Asphalt Light Rehab	$3,074,400	$2,093,517	$1,275,767
15	2031	None	$0	$0	$0
16	2032	None	$0	$0	$0
17	2033	None	$0	$0	$0
18	2034	None	$0	$0	$0
19	2035	None	$0	$0	$0
20	2036	Asphalt Reconstruction	$16,396,800	$9,350,866	$4,533,852
21	2037	None	$0	$0	$0
22	2038	None	$0	$0	$0
23	2039	None	$0	$0	$0
24	2040	None	$0	$0	$0
25	2041	None	$0	$0	$0
26	2042	None	$0	$0	$0
27	2043	None	$0	$0	$0
28	2044	None	$0	$0	$0
29	2045	None	$0	$0	$0
30	2046	None	$0	$0	$0
31	2047	None	$0	$0	$0
32	2048	Asphalt Light Rehab	$3,074,400	$1,229,720	$377,453
33	2049	None	$0	$0	$0
34	2050	None	$0	$0	$0
35	2051	None	$0	$0	$0
36	2052	None	$0	$0	$0
37	2053	None	$0	$0	$0
38	2054	Asphalt Medium Rehab	$4,611,600	$1,544,807	$377,270
39	2055	None	$0	$0	$0
40	2056	None	$0	$0	$0
41	2057	None	$0	$0	$0
42	2058	None	$0	$0	$0
43	2059	None	$0	$0	$0
44	2060	None	$0	$0	$0
45	2061	None	$0	$0	$0
Pick Last Used DA treatment type to calculate Remaining Service Life ››		Asphalt Medium Rehab	$2,818,200	$767,598	$143,577
Enter Year of Last Used DA Improvement ››		2054	Remaining Service Life Cost ^^		

	Net Present Value ($) @ 3%	Net Present Value ($) @ 7%
NET PRESENT VALUE	$17,548,659	$9,938,932
AGENCY COST	$28,950,600	

Design Alternative # 4 - Asphalt Light Rehab

US 89 MP 470 - MP 475

Enter Name of Design Alternative

Number of Years	Year	Asphalt Light Rehab Focus	Agency Cost ($)	Net Present Value @ 3%	Net Present Value @ 7%
0	2016	None	$0	$0	$0
1	2017	None	$0	$0	$0
2	2018	None	$0	$0	$0
3	2019	None	$0	$0	$0
4	2020	None	$0	$0	$0
5	2021	Asphalt Light Rehab	$3,074,400	$2,731,565	$2,345,445
6	2022	None	$0	$0	$0
7	2023	None	$0	$0	$0
8	2024	None	$0	$0	$0
9	2025	None	$0	$0	$0
10	2026	None	$0	$0	$0
11	2027	Asphalt Reconstruction	$16,396,800	$12,200,759	$8,335,302
12	2028	None	$0	$0	$0
13	2029	None	$0	$0	$0
14	2030	None	$0	$0	$0
15	2031	None	$0	$0	$0
16	2032	None	$0	$0	$0
17	2033	None	$0	$0	$0
18	2034	None	$0	$0	$0
19	2035	None	$0	$0	$0
20	2036	None	$0	$0	$0
21	2037	None	$0	$0	$0
22	2038	None	$0	$0	$0
23	2039	Asphalt Light Rehab	$3,074,400	$1,604,506	$693,933
24	2040	None	$0	$0	$0
25	2041	None	$0	$0	$0
26	2042	None	$0	$0	$0
27	2043	None	$0	$0	$0
28	2044	None	$0	$0	$0
29	2045	Asphalt Medium Rehab	$4,611,600	$2,015,623	$693,595
30	2046	None	$0	$0	$0
31	2047	None	$0	$0	$0
32	2048	None	$0	$0	$0
33	2049	None	$0	$0	$0
34	2050	None	$0	$0	$0
35	2051	None	$0	$0	$0
36	2052	None	$0	$0	$0
37	2053	None	$0	$0	$0
38	2054	Asphalt Light Rehab	$3,074,400	$1,029,872	$251,513
39	2055	None	$0	$0	$0
40	2056	None	$0	$0	$0
41	2057	None	$0	$0	$0
42	2058	None	$0	$0	$0
43	2059	None	$0	$0	$0
44	2060	Asphalt Reconstruction	$16,396,800	$4,600,006	$893,834
45	2061	None	$0	$0	$0
Pick Last Used DA treatment type to calculate Remaining Service Life ››		Asphalt Reconstruction	$15,713,600	$4,279,941	$800,552
Enter Year of Last Used DA Improvement ››		2060	Remaining Service Life Cost ^^		

	Net Present Value ($) @ 3%	Net Present Value ($) @ 7%
NET PRESENT VALUE	$19,902,390	$12,413,069
AGENCY COST	$30,914,800	

Summary of LCCA Results

US 89 MP 470 - MP 475

	Concrete Reconstruction	Asphalt Reconstruction	Asphalt Medium Rehab Focus	Asphalt Light Rehab Focus
Net Present Value - 3%	$21,426,935	$22,449,902	$17,548,659	$19,902,390
Net Present Value - 7%	$16,969,950	$15,718,489	$9,938,932	$12,413,069
Agency Cost	$26,946,750	$31,939,600	$28,950,600	$30,914,800

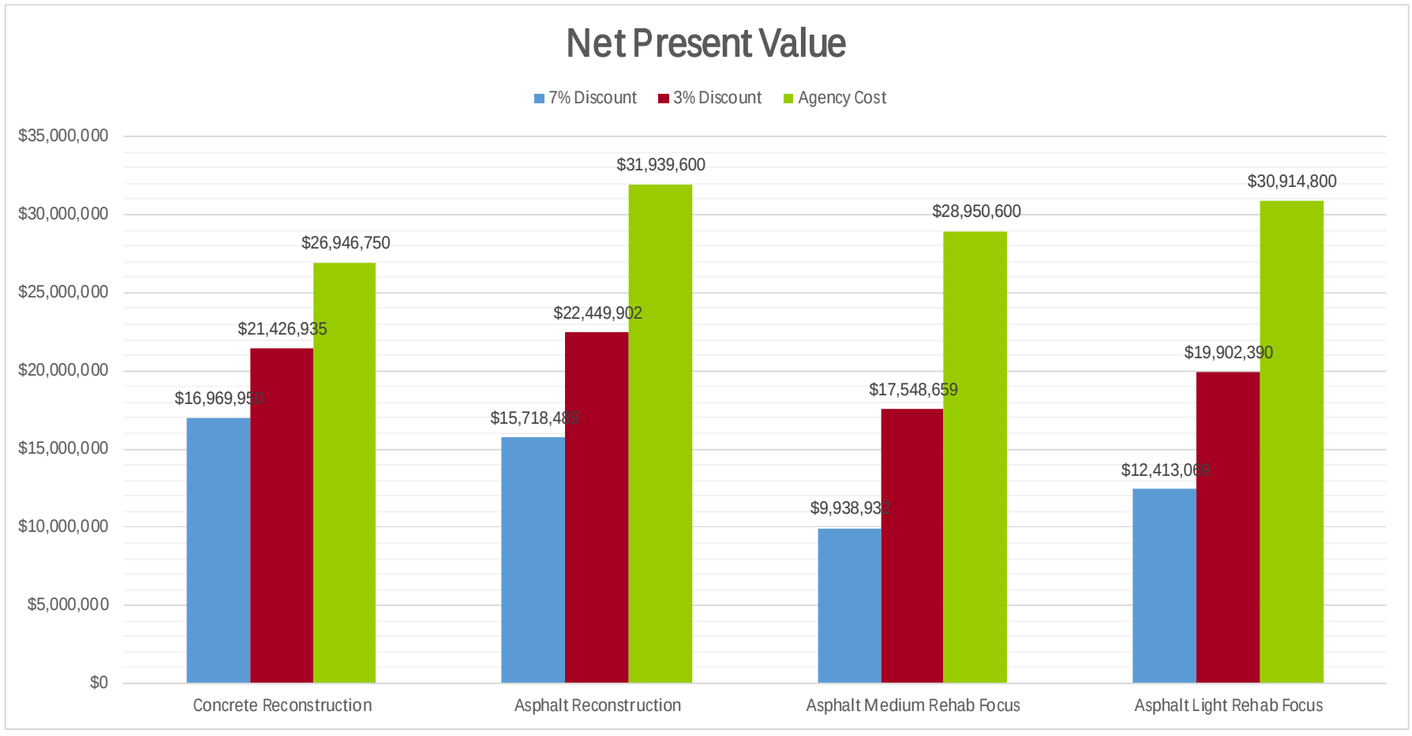
Cost Ratio at 3% Discount Rate

1.22 Ratio of Concrete Reconstruction to Lowest Cost Rehab
1.28 Ratio of Asphalt Reconstruction to Lowest Cost Rehab

Cost Ratio at 7% Discount Rate

1.71 Ratio of Concrete Reconstruction to Lowest Cost Rehab
1.58 Ratio of Asphalt Reconstruction to Lowest Cost Rehab

Note: A cost ratio < 1.15 means the Net Present Value (NPV) of reconstruction is within 15% of the NPV of the lowest cost rehab so reconstruction should likely be the initial improvement solution. A cost ratio > 1.15 means the NPV of reconstruction is more than 15% of the NPV of the lowest cost rehab so rehab should likely be the initial improvement solution.



Appendix F: Crash Modification Factors and Factored Unit Construction Costs

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
REHABILITATION							
Rehabilitate Pavement (AC)	$276,500	Mile	2.20	$610,000	Mill and replace 1"-3" AC pvmt; accounts for 38' width; for one direction of travel on two lane roadway; includes pavement, striping, delineators, RPMs, rumble strips	0.70	Combination of rehabilitate pavement (0.92), striping, delineators, RPMs (0.77 for combination), and rumble strips (0.89) = 0.70
Rehabilitate Bridge	$65	SF	2.20	$140	Based on deck area; bridge only - no other costs included	0.95	Assumed - should have a minor effect on crashes at the bridge
GEOMETRIC IMPROVEMENT							
Re-profile Roadway	$974,500	Mile	2.20	$2,140,000	Includes excavation of approximately 3", pavement replacement (AC), striping, delineators, RPMs, rumble strips, for one direction of travel of 2-lane roadway (38' width)	0.70	Assumed - this is similar to rehab pavement. This solution is intended to address vertical clearance at bridge, not profile issue; factor the cost as a ratio of needed depth to 3".
Realign Roadway	$2,960,000	Mile	2.20	$6,510,000	All costs per direction except bridges; applicable to areas with small or moderate fills and cuts, minimal retaining walls	0.50	Based on CalTrans and NC DOT
Improve Skid Resistance	$675,000	Mile	2.20	$1,490,000	Average cost of pvmt replacement and variable depth paving to increase super-elevation; for one direction of travel on two lane roadway; includes pavement, striping, delineators, RPMs, rumble strips	0.66	Combination of avg of 5 values from clearinghouse (0.77) and calculated value from HSM (0.87) for skid resistance; striping, delineators, RPMs (0.77 for combination), and rumble strips (0.89) = 0.66
INFRASTRUCTURE IMPROVEMENT							
Reconstruct to Urban Section	$1,000,000	Mile	2.20	$2,200,000	Includes widening by 16' total (AC = 12'+2'+2') to provide median, curb & gutter along both side of roadway, single curb for median, striping (doesn't include widening for additional travel lane).	0.88	From HSM
Construct Auxiliary Lanes (AC)	$914,000	Mile	2.20	$2,011,000	For addition of aux lane (AC) in one direction of travel; includes all costs except bridges; for generally at-grade facility with minimal walls and no major drainage improvements	0.78	Average of 4 values from clearinghouse
Construct Climbing Lane (High)	$3,000,000	Mile	2.20	$6,600,000	In one direction; all costs except bridges; applicable to areas with large fills and cuts, retaining walls, rock blasting, steep slopes on both sides of road	0.75	From HSM

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Construct Climbing Lane (Medium)	$2,250,000	Mile	2.20	$4,950,000	In one direction; all costs except bridges; applicable to areas with medium or large fills and cuts, retaining walls, rock blasting, steep slopes on one side of road	0.75	From HSM
Construct Climbing Lane (Low)	$1,500,000	Mile	2.20	$3,300,000	In one direction; all costs except bridges; applicable to areas with small or moderate fills and cuts, minimal retaining walls	0.75	From HSM
Construct Reversible Lane (Low)	$2,400,000	Lane-Mile	2.20	$5,280,000	All costs except bridges; applicable to areas with small or moderate fills and cuts, minimal retaining walls	0.73 for uphill and 0.88 for downhill	Based on proposed conditions on I-17 with 2 reversible lanes and a conc barrier
Construct Reversible Lane (High)	$4,800,000	Lane-Mile	2.20	$10,560,000	All costs except bridges; applicable to areas with large fills and cuts, retaining walls, rock blasting, mountainous terrain	0.73 for uphill and 0.88 for downhill	Based on proposed conditions on I-17 with 2 reversible lanes and a conc barrier
Construct Passing Lane	$1,500,000	Mile	2.20	$3,300,000	In one direction; all costs except bridges; applicable to areas with small or moderate fills and cuts, minimal retaining walls	0.63	Average of 3 values from clearinghouse
Construct Entry/Exit Ramp	$730,000	Each	2.20	$1,610,000	Cost per ramp; includes pavement, striping, signing, RPMs, lighting, typical earthwork & drainage; does not include any major structures or improvements on crossroad	1.09	Average of 16 values on clearinghouse; for adding a ramp not reconstructing. CMF applied to crashes 0.25 miles upstream/downstream from the gore.
Relocate Entry/Exit Ramp	$765,000	Each	2.20	$1,680,000	Cost per ramp; includes pavement, striping, signing, RPMs, lighting, typical earthwork , drainage and demolition of existing ramp; does not include any major structures or improvements on crossroad	1.00	Assumed to not add any crashes since the ramp is simply moving and not being added. CMF applied to crashes 0.25 miles upstream/downstream from the gore.
Construct Turn Lanes	$42,500	Each	2.20	$93,500	Includes 14' roadway widening (AC) for one additional turn lane (250' long) on one leg of an intersection; includes AC pavement, curb & gutter, sidewalk, ramps, striping, and minor signal modifications	0.81	Avg of 7 values from HSM; CMF applied to intersection related crashes; this solution also applies when installing a deceleration lane
Modify Entry/Exit Ramp	$445,000	Each	2.20	$979,000	Cost per ramp; includes pavement, striping, signing, RPMs, lighting, minor earthwork, & drainage; For converting existing ramp to parallel-type configuration	0.21	Average of 4 values from clearinghouse (for exit ramps) and equation from HSM (for entrance ramp). CMF applied to crashes within 1/8 mile upstream/downstream from the gore.

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Widen & Modify Entry/Exit Ramp	$619,000	Each	2.20	$1,361,800	Cost per ramp; includes pavement, striping, signing, RPMs, lighting, minor earthwork, & drainage; For converting 1-lane ramp to 2-lane ramp and converting to parallel-type ramp	0.21	Will be same as "Modify Ramp"
Replace Pavement (AC) (with overexcavation)	$1,446,500	Mile	2.20	$3,180,000	Accounts for 38' width; for one direction of travel on two lane roadway; includes pavement, overexcavation, striping, delineators, RPMs, rumble strips	0.70	Same as rehab
Replace Pavement (PCCP) (with overexcavation)	$1,736,500	Mile	2.20	$3,820,000	Accounts for 38' width; for one direction of travel on two lane roadway; includes pavement, overexcavation, striping, delineators, RPMs, rumble strips	0.70	Same as rehab
Replace Bridge (Short)	$125	SF	2.20	$280	Based on deck area; bridge only - no other costs included; cost developed generally applies to bridges crossing small washes	0.95	Assumed - should have a minor effect on crashes at the bridge
Replace Bridge (Medium)	$160	SF	2.20	$350	Based on deck area; bridge only - no other costs included; cost developed generally applies to bridges crossing over the mainline freeway, crossroads, or large washes	0.95	Assumed - should have a minor effect on crashes at the bridge
Replace Bridge (Long)	$180	SF	2.20	$400	Based on deck area; bridge only - no other costs included; cost developed generally applies to bridges crossing large rivers or canyons	0.95	Assumed - should have a minor effect on crashes at the bridge
Widen Bridge	$175	SF	2.20	$390	Based on deck area; bridge only - no other costs included	0.90	Assumed - should have a minor effect on crashes at the bridge
Install Pedestrian Bridge	$135	SF	2.20	$300	Includes cost to construct bridge based on linear feet of the bridge. This costs includes and assumes ramps and sidewalks leading to the structure.	0.1 (ped only)	Assumed direct access on both sides of structure
Implement Automated Bridge De-icing	$115	SF	2.20	$250	Includes cost to replace bridge deck and install system	0.72 (snow/ice)	Average of 3 values on clearinghouse for snow/ice
Install Wildlife Crossing Under Roadway	$650,000	Each	2.20	$1,430,000	Includes cost of structure for wildlife crossing under roadway and 1 mile of fencing in each direction that is centered on the wildlife crossing	0.25 (wildlife)	Assumed; CMF applies to wildlife-related crashes within 0.5 miles both upstream and downstream of the wildlife crossing in both directions
Install Wildlife Crossing Over Roadway	$1,140,000	Each	2.20	$2,508,000	Includes cost of structure for wildlife crossing over roadway and 1 mile of fencing in each direction that is centered on the wildlife crossing	0.25 (wildlife)	Assumed; CMF applies to wildlife-related crashes within 0.5 miles both upstream and downstream of the wildlife crossing in both directions

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Construct Drainage Structure - Minor	$280,000	Each	2.20	$616,000	Includes 3-36" pipes and roadway reconstruction (approx. 1,000 ft) to install pipes	0.70	Same as rehab; CMF applied to crashes 1/8 mile upstream/downstream of the structure
Construct Drainage Structure - Intermediate	$540,000	Each	2.20	$1,188,000	Includes 5 barrel 8'x6' RCBC and roadway reconstruction (approx. 1,000 ft) to install RCBC	0.70	Same as rehab; CMF applied to crashes 1/8 mile upstream/downstream of the structure
Construct Drainage Structure - Major	$8,000	LF	2.20	$17,600	Includes bridge that is 40' wide and reconstruction of approx. 500' on each approach	0.70	Same as rehab; CMF applied to crashes 1/8 mile upstream/downstream of the structure
Install Acceleration Lane	$127,500	Each	2.20	$280,500	For addition of an acceleration lane (AC) on one leg of an intersection that is 1,000' long plus a taper; includes all costs except bridges; for generally at-grade facility with minimal walls and no major drainage improvements	0.85	Average of 6 values from the FHWA Desktop Reference for Crash Reduction Factors
OPERATIONAL IMPROVEMENT							
Implement Variable Speed Limits (Wireless, Overhead)	$718,900	Mile	2.20	$1,580,000	In one direction; includes 1 sign assembly per mile (foundation and structure), wireless communication, detectors	0.92	From 1 value from clearinghouse
Implement Variable Speed Limits (Wireless, Ground-mount)	$169,700	Mile	2.20	$373,300	In one direction; includes 2 signs per mile (foundations and posts), wireless communication, detectors	0.92	From 1 value from clearinghouse
Implement Variable Speed Limits (Wireless, Solar, Overhead)	$502,300	Mile	2.20	$1,110,000	In one direction; includes 1 sign assembly per mile (foundation and structure), wireless communication, detectors, solar power	0.92	From 1 value from clearinghouse
Implement Variable Speed Limits (Wireless, Solar, Ground-mount)	$88,400	Mile	2.20	$194,500	In one direction; includes 2 signs per mile (foundations and posts), wireless communication, detectors, solar power	0.92	From 1 value from clearinghouse
Implement Ramp Metering (Low)	$25,000	Each	2.20	$55,000	For each entry ramp location; urban area with existing ITS backbone infrastructure; includes signals, poles, cabinet, detectors, pull boxes, etc	0.64	From 1 value from clearinghouse; CMF applied to crashes 0.25 miles after gore
Implement Ramp Metering (High)	$150,000	Mile	2.20	$330,000	Area without existing ITS backbone infrastructure; in addition to ramp meters, also includes conduit, fiber optic lines, and power	0.64	From 1 value from clearinghouse
Implement Signal Coordination	$140,000	Mile	2.20	$308,000	Includes conduit, conductors, and controllers for 4 intersections that span a total of approximately 2 miles	0.90	Assumed

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Implement Left-Turn Phasing	$7,500	Each	2.20	$16,500	Includes four new signal heads (two in each direction) and associated conductors for one intersection	0.88 (protected) 0.98 (perm/prot or prot/perm)	From HSM; CMF = 0.94 for each protected approach and 0.99 for each perm/prot or prot/perm approach. CMFs of different approaches should be multiplied together. CMF applied to crashes within intersection
ROADSIDE DESIGN							
Install Guardrail	$130,000	Mile	2.20	$286,000	One side of road	0.62 (ROR)	0.62 is avg of 2 values from clearinghouse
Install Cable Barrier	$80,000	Mile	2.20	$176,000	In median	0.81	0.81 is average of 5 values from clearinghouse
Widen Shoulder (AC)	$256,000	Mile	2.20	$563,000	Assumes 10' of existing shoulder (combined left and right), includes widening shoulder by a total of 4'; new pavement for 4' width and mill and replace existing 10' width; includes pavement, minor earthwork, striping edge lines, RPMs, high-visibility delineators, safety edge, and rumble strips	0.68 (1-4') 0.64 (>= 4')	0.86 is avg of 5 values from clearing house for widening shoulder 1-4'. 0.76 is calculated from HSM for widening shoulder >= 4'. (Cost needs to be updated if dimension of existing and widened shoulder differ from Description.)
Rehabilitate Shoulder (AC)	$113,000	Mile	2.20	$249,000	One direction of travel (14' total shldr width-4' left and 10' right); includes paving (mill and replace), striping, high-visibility delineators, RPMs, safety edge, and rumble strips for both shoulders	0.72	0.98 is average of 34 values on clearinghouse for shldr rehab/replace; include striping, delineators, RPMs (0.77 combined CMF), and rumble strips (0.89). (Cost needs to be updated if dimension of existing shoulder differs from Description.)
Replace Shoulder (AC)	$364,000	Mile	2.20	$801,000	One direction of travel (14' total shldr width-4' left and 10' right); includes paving (full reconstruction), striping, high-visibility delineators, RPMs, safety edge, and rumble strips for both shoulders	0.72	0.98 is average of 34 values on clearinghouse for shldr rehab/replace; include striping, delineators, RPMs (0.77 combined CMF), and rumble strips (0.89). (Cost needs to be updated if dimension of existing shoulder differs from Description.)
Install Rumble Strip	$5,500	Mile	2.20	$12,000	Both edges - one direction of travel; includes only rumble strip; no shoulder rehab or paving or striping	0.89	Average of 75 values on clearinghouse and consistent with HSM
Install Centerline Rumble Strip	$2,800	Mile	2.20	$6,000	Includes rumble strip only; no pavement rehab or striping	0.85	From HSM
Install Wildlife Fencing	$340,000	Mile	2.20	$748,000	Fencing only plus jump outs for 1 mile (both directions)	0.50 (wildlife)	Assumed

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Remove Tree/Vegetation	$200,000	Mile	2.20	$440,000	Intended for removing trees that shade the roadway to allow sunlight to help melt snow and ice (see Increase Clear Zone CMF for general tree/vegetation removal in clear zone)	0.72 (snow/ice)	Average of 3 values on clearinghouse for snow/ice
Increase Clear Zone	$59,000	Mile	2.20	$130,000	In one direction; includes widening the clear zone by 10' to a depth of 3'	0.71	Median of 14 values from FHWA Desktop Reference for Crash Reduction Values
Install Access Barrier Fence	$15	LF	2.20	$33	8' fencing along residential section of roadway	0.10 (ped only)	Equal to ped overpass
Install Rock-Fall Mitigation - Wire Mesh	$1,320,000	Mile	2.20	$2,904,000	Includes wire mesh and rock stabilization (one direction)	0.75 (debris)	Assumed
Install Rock-Fall Mitigation - Containment Fence & Barrier	$2,112,000	Mile	2.20	$4,646,000	Includes containment fencing, concrete barrier, and rock stabilization (one direction)	0.75 (debris)	Assumed
Install Raised Concrete Barrier in Median	$650,000	Mile	2.20	$1,430,000	Includes concrete barrier with associated striping and reflective markings; excludes lighting in barrier (one direction)	0.90 (Cross-median and head on crashes eliminated completely)	All cross median and head-on fatal or incapacitating injury crashes are eliminated completely; all remaining crashes have 0.90 applied
Formalize Pullout (Small)	$7,500	Each	2.20	$17,000	Includes paving and signage (signs, posts, and foundations) - approximately 4,200 sf	0.97	Assumed - similar to Install Other General Warning Signs; CMF applied to crashes within 0.25 miles after sign
Formalize Pullout (Medium)	$27,500	Each	2.20	$61,000	Includes paving and signage (signs, posts, and foundations) - approximately 22,500 sf	0.97	Assumed - similar to Install Other General Warning Signs; CMF applied to crashes within 0.25 miles after sign
Formalize Pullout (Large)	$80,500	Each	2.20	$177,100	Includes paving and signage (signs, posts, and foundations) - approximately 70,000 sf	0.97	Assumed - similar to Install Other General Warning Signs; CMF applied to crashes within 0.25 miles after sign
INTERSECTION IMPROVEMENTS							
Construct Traffic Signal	$150,000	Each	2.20	$330,000	4-legged intersection; includes poles, foundations, conduit, controller, heads, luminaires, mast arms, etc.	0.95	From HSM; CMF applied to crashes within intersection only
Improve Signal Visibility	$35,000	Each	2.20	$77,000	4-legged intersection; signal head size upgrade, installation of new back-plates, and installation of additional signal heads on new poles.	0.85	Avg of 7 values from clearinghouse; CMF applied to crashes within intersection only

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Install Raised Median	$360,000	Mile	2.20	$792,000	Includes removal of 14' wide pavement and construction of curb & gutter; does not include cost to widen roadway to accommodate the median; if the roadway needs to be widened, include cost from New General Purpose Lane	0.83	Avg from HSM
Install Transverse Rumble Strip/Pavement Markings	$3,000	Each	2.20	$7,000	Includes ped markings and rumble strips only across a 30' wide travelway; no pavement rehab or other striping	0.95	Avg of 17 values from clearinghouse; CMF applied to crashes within 0.5 miles after the rumble strips and markings
Construct Single-Lane Roundabout	$1,500,000	Each	2.20	$3,300,000	Removal of signal at 4-legged intersection; realignment of each leg for approx. 800 feet including paving, curbs, sidewalk, striping, lighting, signing	0.22	From HSM; CMF applied to crashes within intersection only
Construct Double-Lane Roundabout	$1,800,000	Each	2.20	$3,960,000	Removal of signal at 4-legged intersection; realignment of each leg for approx. 800 feet including paving, curbs, sidewalk, striping, lighting, signing	0.40	From HSM; CMF applied to crashes within intersection only
ROADWAY DELINEATION							
Install High-Visibility Edge Line Striping	$10,800	Mile	2.20	$23,800	2 edge lines and lane line - one direction of travel	0.77	Avg of 3 values from clearinghouse. Assumes package of striping, delineators, and RPMs. (If implemented separately, CMF will be higher.)
Install High-Visibility Delineators	$6,500	Mile	2.20	$14,300	Both edges - one direction of travel		Avg of 3 values from clearinghouse. Assumes package of striping, delineators, and RPMs. (If implemented separately, CMF will be higher.)
Install Raised Pavement Markers	$2,000	Mile	2.20	$4,400	Both edges - one direction of travel		Avg of 3 values from clearinghouse. Assumes package of striping, delineators, and RPMs. (If implemented separately, CMF will be higher.)
Install In-Lane Route Markings	$6,000	Each	2.20	$13,200	Installation of a series of three in-lane route markings in one lane	0.95	Assumed; CMF applied to crashes within 1.0 mile before the gore
IMPROVED VISIBILITY							
Cut Side Slopes	$80	LF	2.20	$200	For small grading to correct sight distance issues; not major grading	0.85	Intent of this solution is to improve sight distance. Most CMF's are associated with vehicles traveling on slope. Recommended CMF is based on FDOT and NCDOT but is more conservative.

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Install Lighting (connect to existing power)	$270,000	Mile	2.20	$594,000	One side of road only; offset lighting, not high-mast; does not include power supply; includes poles, luminaire, pull boxes, conduit, conductor	0.75 (night)	Average of 3 values on clearinghouse & consistent with HSM
Install Lighting (solar powered LED)	$10,000	Pole	2.20	$22,000	Offset lighting, not high-mast; solar power LED; includes poles, luminaire, solar panel	0.75 (night)	Average of 3 values on clearinghouse & consistent with HSM
DRIVER INFORMATION/WARNING							
Install Dynamic Message Sign (DMS)	$250,000	Each	2.20	$550,000	Includes sign, overhead structure, and foundations; wireless communication; does not include power supply	1.00	Not expected to reduce crashes
Install Dynamic Weather Warning Beacons	$40,000	Each	2.20	$88,000	Assumes solar operation and wireless communication or connection to existing power and communication; ground mounted; includes posts, foundations, solar panel, and dynamic sign	0.80 (weather related)	Avg of 3 values from FHWA Desktop Reference for Crash Reduction Factors; CMF applies to crashes within 0.25 miles after a sign
Install Dynamic Speed Feedback Signs	$25,000	Each	2.20	$55,000	Assumes solar operation and no communication; ground mounted; includes regulatory sign, posts, foundations, solar panel, and dynamic sign	0.94	Average of 2 clearinghouse values; CMF applies to crashes within 0.50 miles after a sign
Install Chevrons	$18,400	Mile	2.20	$40,500	On one side of road - includes signs, posts, and foundations	0.79	Average of 11 clearinghouse values
Install Curve Warning Signs	$2,500	Each	2.20	$5,500	Includes 2 signs, posts, and foundations	0.83	Average of 4 clearinghouse values; CMF applies to crashes within 0.25 miles after a sign
Install Traffic Control Device Warning Signs (e.g., stop sign ahead, signal ahead, etc.)	$2,500	Each	2.20	$5,500	Includes 2 signs, posts, and foundations	0.85	FHWA Desktop Reference for Crash Reduction Factors; CMF applies to crashes within 0.25 miles after a sign
Install Other General Warning Signs (e.g., intersection ahead, wildlife in area, slow vehicles, etc.)	$2,500	Each	2.20	$5,500	Includes 2 signs, posts, and foundations	0.97	Assumed; CMF applies to crashes within 0.25 miles after a sign
Install Wildlife Warning System	$162,000	Each	2.20	$356,400	Includes wildlife detection system at a designated wildlife crossing, flashing warning signs (assumes solar power), advance signing, CCTV (solar and wireless), game fencing for approximately 0.25 miles in each direction - centered on the wildlife crossing, and regular fencing for 1.0 mile in each direction - centered on the wildlife crossing.	0.50 (wildlife)	Assumed; CMF applies to wildlife-related crashes within 0.5 miles both upstream and downstream of the wildlife crossing in both directions

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Install Warning Sign with Beacons	$15,000	Each	2.20	$33,000	In both directions; includes warning sign, post, and foundation, and flashing beacons (assumes solar power) at one location	0.75	FHWA Desktop Reference for Crash Reduction Factors for Installing Flashing Beacons as Advance Warning; CMF applies to crashes within 0.25 miles after a sign
Install Larger Stop Sign with Beacons	$10,000	Each	2.20	$22,000	In one direction; includes large stop sign, post, and foundation, and flashing beacons (assumes solar power) at one location	0.85/0.81	Use 0.85 for adding beacons to an existing sign; 0.81 for installing a larger sign with flashing beacons; CMF applies to intersection related crashes
DATA COLLECTION							
Install Roadside Weather Information System (RWIS)	$60,000	Each	2.20	$132,000	Assumes wireless communication and solar power, or connection to existing power and communications	1.00	Not expected to reduce crashes
Install Closed Circuit Television (CCTV) Camera	$25,000	Each	2.20	$55,000	Assumes connection to existing ITS backbone or wireless communication; does not include fiber-optic backbone infrastructure; includes pole, camera, etc	1.00	Not expected to reduce crashes
Install Vehicle Detection Stations	$15,000	Each	2.20	$33,000	Assumes wireless communication and solar power, or connection to existing power and communications	1.00	Not expected to reduce crashes
Install Flood Sensors (Activation)	$15,000	Each	2.20	$33,000	Sensors with activation cabinet to alert through texting (agency)	1.00	Not expected to reduce crashes
Install Flood Sensors (Gates)	$100,000	Each	2.20	$220,000	Sensors with activation cabinet to alert through texting (agency) and beacons (public) plus gates	1.00	Not expected to reduce crashes
WIDEN CORRIDOR							
Construct New General Purpose Lane (PCCP)	$1,740,000	Mile	2.20	$3,830,000	For addition of 1 GP lane (PCCP) in one direction; includes all costs except bridges; for generally at-grade facility with minimal walls and no major drainage improvements	0.90	North Carolina DOT uses 0.90 and Florida DOT uses 0.87
Construct New General Purpose Lane (AC)	$1,200,000	Mile	2.20	$2,640,000	For addition of 1 GP lane (AC) in one direction; includes all costs except bridges; for generally at-grade facility with minimal walls and no major drainage improvements	0.90	North Carolina DOT uses 0.90 and Florida DOT uses 0.88
Convert a 2-Lane undivided highway to a 5-Lane highway	$1,576,000	Mile	2.20	$3,467,200	For expanding a 2-lane undivided highway to a 5-lane highway (4 through lanes with TWLTL), includes standard shoulder widths but no curb, gutter, or sidewalks	0.60	Assumed to be slightly lower than converting from a 4-lane to a 5-lane highway

SOLUTION	CONSTRUCTION UNIT COST	UNIT	FACTOR^	FACTORED CONSTRUCTION UNIT COST	DESCRIPTION	CMF FOR CORRIDOR PROFILE STUDIES	CMF NOTES
Install Center Turn Lane	$1,053,000	Mile	2.20	$2,316,600	For adding a center turn lane (i.e., TWLTL); assumes symmetrical widening on both sides of the road; includes standard shoulder widths but no curb, gutter, or sidewalk	0.75	From FHWA Desktop Reference for Crash Reduction Factors, CMF Clearinghouse, and SR 87 CPS comparison
Construct 4-Lane Divided Highway (Using Existing 2-Lane Road for one direction)	$3,000,000	Mile	2.20	$6,600,000	In both directions; one direction uses existing 2-lane road; other direction assumes addition of 2 new lanes (AC) with standard shoulders; includes all costs except bridges	0.67	Assumed
Construct 4-Lane Divided Highway (No Use of Existing Roads)	$6,000,000	Mile	2.20	$13,200,000	In both directions; assumes addition of 2 new lanes (AC) with standard shoulders in each direction; includes all costs except bridges	0.67	Assumed
Construct Bridge over At-Grade Railroad Crossing	$10,000,000	Each	2.20	$22,000,000	Assumes bridge width of 4 lanes (AC) with standard shoulders; includes abutments and bridge approaches; assumes vertical clearance of 23'4" + 6'8" superstructure	0.72 (All train-related crashes eliminated)	Removes all train-related crashes at at-grade crossing; all other crashes CMF = 0.72
Construct Underpass at At-Grade Railroad Crossing	$15,000,000	Each	2.20	$33,000,000	Assumes underpass width of 4 lanes (AC) with standard shoulders; includes railroad bridge with abutments and underpass approaches; assumes vertical clearance of 16'6" + 6'6" superstructure	0.72 (All train-related crashes eliminated)	Removes all train-related crashes at at-grade crossing; all other crashes CMF = 0.72
Construct High-Occupancy Vehicle (HOV) Lane	$900,000	Mile	2.20	$1,980,000	For addition of 1 HOV lane (AC) in one direction with associated signage and markings; includes all costs except bridges; for generally at-grade facility with minimal walls and no major drainage improvements	0.95	Similar to general purpose lane
ALTERNATE ROUTE							
Construct Frontage Roads	$2,400,000	Mile	2.20	$5,280,000	For 2-lane AC frontage road; includes all costs except bridges; for generally at-grade facility with minimal walls	0.90	Assumed - similar to new general purpose lane
Construct 2-Lane Undivided Highway	$3,000,000	Mile	2.20	$6,600,000	In both directions; assumes addition of 2 new lanes (AC) with standard shoulders in each direction; includes all costs except bridges	0.90	Assuming new alignment for a bypass

^ Factor accounts for traffic control, erosion control, construction surveying and quality control, mobilization, construction engineering, contingencies, indirect cost allocation, and miscellaneous work

Appendix G: Performance Area Risk Factors

Pavement Performance Area

- Mainline Daily Traffic Volume
- Mainline Daily Truck Volume
- Elevation
- Interrupted Flow

Elevation

Variance above 4000' divided by 1000; (Elev-4000)/1000

Score	Condition
0	< 4000’
0-5	4000’- 9000’
5	> 9000’

Mainline Daily Traffic Volume

Exponential equation; score = $5-(5*e^{(ADT*-0.000039)})$

Score	Condition
0	< 6,000
0-5	6,000 – 160,000
5	>160,000

Mainline Daily Truck Volume

Exponential equation; score = $5-(5*e^{(ADT*-0.00025)})$

Score	Condition
0	<900
0-5	900-25,000
5	>25,000

Interrupted Flow

Score	Condition
0	Not interrupted flow
5	Interrupted Flow

Bridge Performance Area

- Mainline Daily Traffic Volume
- Detour Length
- Elevation
- Scour Critical Rating
- Carries Mainline Traffic
- Vertical Clearance

Mainline Daily Traffic Volume

Exponential equation; score = $5-(5*e^{(ADT*-0.000039)})$

Score	Condition
0	<6,000
0-5	6,000-160,000
5	>160,000

Elevation

Variance above 4000' divided by 1000; (Elev-4000)/1000

Score	Condition
0	< 4000’
0-5	4000’- 9000’
5	> 9000’

Carries Mainline

Score	Condition
0	Does not carry mainline traffic
5	Carries mainline traffic

Detour Scale

Divides detour length by 10 and multiplies by 2.5

Score	Condition
0	0 miles
0-5	0-20 miles
5	> 20 miles

Scour

Variance below 8

Score	Condition
0	Rating > 8
0-5	Rating 8 - 3
5	Rating < 3

Vertical Clearance

Variance below 16’ x 2.5; (16 –Clearance) x 2.5

Score	Condition
0	>16’
0-5	16’-14’
5	<14’

Mobility Performance Area

- Mainline VMT
- Detour Length
- Buffer Index (PTI-TTI)
- Shoulder Width

Mainline VMT

Exponential equation; score = 5-(5*e$^{(ADT*-0.0000139)}$)

Score	Condition
0	<16,000
0-5	16,000-400,000
5	>400,000

Buffer Index

Buffer Index x 10

Score	Condition
0	Buffer Index = 0.00
0-5	Buffer Index 0.00-0.50
5	Buffer Index > 0.50

Detour Length

Score	Condition
0	Detour < 10 miles
5	Detour > 10 miles

Shoulder Width

Variance below 10’, if only 1 lane in each direction

Score	Condition
0	10’ or above or >1 lane in each direction
0-5	10’-5’ and 1 lane in each direction
5	5’ or less and 1 lane in each direction

Safety Performance Area

- Mainline Daily Traffic Volume
- Vertical Grade
- Shoulder width (Right)
- Elevation
- Interrupted Flow

Mainline Daily Traffic Volume

Exponential equation; score = 5-(5*e$^{(ADT*-0.000039)}$)

Score	Condition
0	<6,000
0-5	6,000-160,000
5	>160,000

Interrupted Flow

Score	Condition
0	Not interrupted flow
5	Interrupted Flow

Elevation

Variance above 4000' divided by 1000; (Elev-4000)/1000

Score	Condition
0	< 4000’
0-5	4000’- 9000’
5	> 9000’

Shoulder Right side)

Variance below 10'

Score	Condition
0	10’ or above
0-5	10’ - 5’
5	5’ or less

Grade

Variance above 3% x 1.5

Score	Condition
0	< 3%
0-5	3% - 6.33%
5	>6.33%

Freight Performance Area

- Mainline Daily Truck Volume
- Detour Length
- Truck Buffer Index (TPTI-TTTI)
- Shoulder Width

Mainline Daily Truck Volume

Exponential equation; score = 5-(5*e$^{(ADT*-0.00025)}$)

Score	Condition
0	<900
0-5	900-25,000
5	>25,000

Detour Length

Score	Condition
0	Detour < 10 miles
5	Detour > 10 miles

Truck Buffer Index

Truck Buffer Index x 10

Score	Condition
0	Buffer Index = 0.00
0-5	Buffer Index 0.00-0.50
5	Buffer Index > 0.50

Shoulder Width

Variance below 10’, if only 1 lane in each direction

Score	Condition
0	10’ or above or >1 lane in each direction
0-5	10’-5’ and 1 lane in each direction
5	5’ or less and 1 lane in each direction

Solution Number	Mainline Traffic Vol (vpd) (2-way)	Solution Length (miles)	Bridge Detour Length (miles) (N19)	Elevation (ft)	Scour Critical Rating (0-9)	Carries Mainline Traffic (Y/N)	Bridge Vert. Clear (ft)	Mainline Truck Vol (vpd) (2-way)	Detour Length > 10 miles (Y/N)	Truck Buffer Index	Non-Truck Buffer Index	Grade (%)	Interrupted Flow (Y/N)	Outside/ Right Shoulder Width (ft)	1-lane each direction
89U.1	6,026	4		7,280				1,139	y	0.42	0.4	3.3	n	9	n
89U.2	6,026	4		6,350				1,139	y	0.42	0.4	2.3	n	4	n
89U.3A	7,330	8		4,370				985	y	0.79	0.94	1.4	n	6	y
89U.3B	7,330	8		4,370				985	y	0.79	0.94	1.4	n	6	y
89U.5	3,489	2.5		6,070				530	y	1.36	1.69	2.5	n	4	y
89U.6	3,489	10		5,670				530	y	1.36	1.69	1.1	n	4	y
89U.7	5,385	1		4,080				821	n	2.65	1.79	2	y	5	y

Solution Number	Bridge	Pavement	Mobility	Safety	Freight	Risk Score (0 to 10)				
						Bridge	Pavement	Mobility	Safety	Freight
89U.1	n	n	y	y	y	0.00	0.00	5.21	2.31	5.22
89U.2	n	n	y	y	y	0.00	0.00	5.21	3.36	5.22
89U.3A	n	y	y	y	y	0.00	1.80	8.39	2.24	7.55
89U.3B	n	y	y	y	y	0.00	1.80	8.39	2.24	7.55
89U.5	n	y	y	y	y	0.00	2.22	7.79	3.08	7.81
89U.6	n	n	y	y	y	0.00	0.00	8.46	2.92	7.81
89U.7	n	y	y	y	y	0.00	1.30	3.37	4.41	3.99

Appendix H: Candidate Solution Cost Estimates

SOLUTION		QUANTITY	UNIT	UNIT COST	TOTAL CONSTRUCTION COST	NOTES
CS89U.1	Sunset Crater Safety Improvement					
	Install edge line striping (northbound)	4	Mile	$23,800	$95,200	
	Install delineators (northbound)	4	Mile	$14,300	$57,200	
	Install RPM's (northbound)	4	Mile	$4,400	$17,600	
	Install rumble strip (northbound)	4	Mile	$12,000	$48,000	
	Install edge line striping (southbound)	4	Mile	$23,800	$95,200	
	Install delineators (southbound)	4	Mile	$14,300	$57,200	
	Install RPM's (southbound)	4	Mile	$4,400	$17,600	
	Install rumble strip (southbound)	4	Mile	$12,000	$48,000	
	Install chevrons	1	Mile	$40,500	$40,500	
				CONSTRUCTION SUBTOTAL	$480,000	
			3%	Preliminary Eng	$10,000	
			10%	Design	$50,000	
				TOTAL	$540,000	
CS89U.2	Antelope Hills Safety Improvement					
	Install edge line striping (northbound)	4	Mile	$23,800	$95,200	
	Install delineators (northbound)	4	Mile	$14,300	$57,200	
	Install RPM's (northbound)	4	Mile	$4,400	$17,600	
	Install rumble strip (northbound)	4	Mile	$12,000	$48,000	
	Install edge line striping (southbound)	4	Mile	$23,800	$95,200	
	Install delineators (southbound)	4	Mile	$14,300	$57,200	
	Install RPM's (southbound)	4	Mile	$4,400	$17,600	
	Install rumble strip (southbound)	4	Mile	$12,000	$48,000	
	Install roadway lighting (northbound)	4	Mile	$594,000	$2,376,000	
	Install roadway lighting (southbound)	4	Mile	$594,001	$2,376,000	
	Install chevrons	1	Mile	$40,500	$40,500	
				CONSTRUCTION SUBTOTAL	$5,230,000	
			3%	Preliminary Eng	$160,000	
			10%	Design	$520,000	
				TOTAL	$5,910,000	

SOLUTION		QUANTITY	UNIT	UNIT COST	TOTAL CONSTRUCTION COST	NOTES
CS89U.3	North Cameron Safety Improvement					
	OPTION A					
	Construct 4-lane dvided highway (use exst 2-lane road for 1 direction)	8	Mile	$6,600,000	$52,800,000	
				CONSTRUCTION SUBTOTAL	$52,800,000	
			3%	Preliminary Eng	$1,580,000	
			10%	Design	$5,300,000	
				TOTAL	$59,680,000	
	OPTION B					
	Construct SB passing lane	1	Mile	$3,300,000	$3,300,000	
	Widen shoulder	4	Mile	$950,000	$3,800,000	$950k per mile for a total widening of 12'
	Install edge line striping (northbound)	4	Mile	$23,800	$95,200	
	Install delineators (northbound)	4	Mile	$14,300	$57,200	
	Install RPM's (northbound)	4	Mile	$4,400	$17,600	
	Install rumble strip (northbound)	4	Mile	$12,000	$48,000	
	Install edge line striping (southbound)	3	Mile	$23,800	$71,400	
	Install delineators (southbound)	3	Mile	$14,300	$42,900	
	Install RPM's (southbound)	3	Mile	$4,400	$13,200	
	Install rumble strip (southbound)	3	Mile	$12,000	$36,000	
				CONSTRUCTION SUBTOTAL	$7,480,000	
			3%	Preliminary Eng	$224,000	
			10%	Design	$748,000	
				TOTAL	$8,452,000	
CS89U.5	Waterhole Canyon Freight Improvement					
	Construct NB passing lane	1	Mile	$3,300,000	$3,300,000	
	Construct SB passing lane	1.5	Mile	$3,300,000	$4,950,000	
				CONSTRUCTION SUBTOTAL	$8,250,000	
			3%	Preliminary Eng	$248,000	
			10%	Design	$825,000	
				TOTAL	$9,323,000	

	SOLUTION	QUANTITY	UNIT	UNIT COST	TOTAL CONSTRUCTION COST	NOTES
CS89U.6	Waterhole Canyon Safety Improvement					
	Install edge line striping (northbound)	3	Mile	$23,800	$70,000	
	Install delineators (northbound)	3	Mile	$14,300	$40,000	
	Install RPM's (northbound)	3	Mile	$4,400	$10,000	
	Install rumble strip (northbound)	3	Mile	$12,000	$40,000	
	Install edge line striping (southbound)	3	Mile	$23,800	$70,000	
	Install delineators (southbound)	3	Mile	$14,300	$40,000	
	Install RPM's (southbound)	3	Mile	$4,400	$10,000	
	Install rumble strip (southbound)	3	Mile	$12,000	$40,000	
	Install guardrail (northbound)	1	Mile	$286,000	$286,000	
	Install guardrail (southbound)	1	Mile	$286,000	$286,000	
	Install chevrons	0.5	Mile	$40,500	$20,300	
	Widen shoulder	10	Mile	$950,000	$9,500,000	$950k per mile for a total widening of 12'
	Install centerline rumble strip	13	Mile	$6,000	$78,000	
				CONSTRUCTION SUBTOTAL	$10,490,000	
			3%	Preliminary Eng	$315,000	
			10%	Design	$1,049,000	
				TOTAL	$11,854,000	
CS89U.7	Page Intersection Safety Improvement					
	Construct single-lane roundabout	2	Each	$3,300,000	$6,600,000	
	Install raised median	1.75	Mile	$792,000	$1,386,000	
				CONSTRUCTION SUBTOTAL	$7,990,000	
			3%	Preliminary Eng	$240,000	
			10%	Design	$800,000	
	Right-of-Way	200,000	SF	$12	$2,400,000	
				TOTAL	$11,430,000	

Appendix I: Performance Effectiveness Scores

Post-Project Performance Scores

LEGEND:

- user entered value
- calculated value for reference only
- calculated value for entry/use in other spreadsheet
- for input into Performance Effectiveness Score spreadsheet
- assumed values (do not modify)

			Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
			Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
			Project Beg MP	428	436	467	467	531	534	547
			Project End MP	432	440	475	475	535	547	548.75
			Project Length (miles)	4	4	8	8	4	13	1.75
			Segment Beg MP	428	428	465	465	524	524	547
			Segment End MP	442	442	481	481	547	547	550
			Segment Length (miles)	14	14	16	16	23	23	3
			Segment #	2	2	5	5	8	8	9
			Current # of Lanes (both directions)	4	4	2	2	2	2	2
			Project Type (one-way or two-way)	two-way	two-way	two-way	two-way	two-way	two-way	two-way
			Additional Lanes (one-way)	0	0	1	0	0	0	0
			Pro-Rated # of Lanes	4.00	4.00	3.00	2.00	2.00	2.00	2.00
		Notes and Directions	Description							
SAFETY	DIRECTIONAL SAFETY	Input current value from performance system (direction 1)	Orig Segment Directional Safety Index (NB)	2.010	2.010	1.480	1.480	1.290	1.290	0.510
		Input current value from performance system (direction 1)	Orig Segment Directional Fatal Crashes (NB)	3	3	2	2	1	1	0
		Input current value from performance system (direction 1)	Orig Segment Directional Incap Crashes (NB)	4	4	3	3	4	4	2
		Input current value from performance system (direction 1)	Original Fatal Crashes in project limits (NB)	1	Offline Calc	2	Offline Calc	1	Offline Calc	0
		Input current value from performance system (direction 1)	Original Incap Crashes in project limits (NB)	1	Offline Calc	2	Offline Calc	0	Offline Calc	2
		Input CMF value (direction 1) - If no CMF enter 1.0	CMF 1 (NB)(lowest CMF)	0.77	Offline Calc	0.67	Offline Calc	0.63	Offline Calc	0.22
		Input CMF value (direction 1) - If no CMF enter 1.0	CMF 2 (NB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Input CMF value (direction 1) - If no CMF enter 1.1	CMF 3 (NB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Input CMF value (direction 1) - If no CMF enter 1.2	CMF 4 (NB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Input CMF value (direction 1) - If no CMF enter 1.0	CMF 5 (NB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Calculated Value (direction 1)	Total CMF (NB)	0.770	N/A	0.670	N/A	0.630	N/A	0.220
		Calculated Value (direction 1)	Fatal Crash reduction (NB)	0.230	0.566	0.660	0.590	0.370	0.288	0.000
		Calculated Value (direction 1)	Incap Crash reduction (NB)	0.230	0.336	0.660	0.230	0.000	1.632	1.560
		Enter in Safety Index spreadsheet to calculate new Safety Index (direction 1)	Post-Project Segment Directional Fatal Crashes (NB)	2.770	2.434	1.340	1.410	0.630	0.712	0.000
		Enter in Safety Index spreadsheet to calculate new Safety Index (direction 1)	Post-Project Segment Directional Incap Crashes (NB)	3.770	3.664	2.340	2.770	4.000	2.368	0.440
		Input value from updated Safety Index spreadsheet (direction 1)	Post-Project Segment Directional Safety Index (NB)	1.860	1.650	1.010	1.080	0.920	0.880	0.110

			Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
			Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
LEGEND:			Project Beg MP	428	436	467	467	531	534	547
		- user entered value	Project End MP	432	440	475	475	535	547	548.75
		Enter in Safety Needs spreadsheet to calculate new segment level Safety Need (direction 1)	Post-Project Segment Directional Safety Index (NB)	1.860	1.650	1.010	1.080	0.920	0.880	0.110
		Input current value from performance system (direction 2)	Orig Segment Directional Safety Index (SB)	0.250	0.250	1.370	1.380	1.090	1.090	4.470
		Input current value from performance system (direction 2)	Orig Segment Directional Fatal Crashes (SB)	0	0	2	2	1	1	1
		Input current value from performance system (direction 2)	Orig Segment Directional Incap Crashes (SB)	6	6	1	1	1	1	3
		Input current value from performance system (direction 2)	Original Fatal Crashes in project limits (SB)	0	Offline Calc	2	Offline Calc	1	Offline Calc	1
		Input current value from performance system (direction 2)	Original Incap Crashes in project limits (SB)	2	Offline Calc	1	Offline Calc	0	Offline Calc	2
		Input CMF value (direction 2) - If no CMF enter 1.0	CMF 1 (SB)(lowest CMF)	0.77	Offline Calc	0.67	Offline Calc	0.63	Offline Calc	0.22
		Input CMF value (direction 2) - If no CMF enter 1.0	CMF 2 (SB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Input CMF value (direction 2) - If no CMF enter 1.1	CMF 3 (SB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Input CMF value (direction 2) - If no CMF enter 1.2	CMF 4 (SB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Input CMF value (direction 2) - If no CMF enter 1.0	CMF 5 (SB)	1	Offline Calc	1	Offline Calc	1	Offline Calc	1
		Calculated Value (direction 2)	Total CMF (SB)	0.770	N/A	0.670	N/A	0.630	N/A	0.220
		Calculated Value (direction 2)	Fatal Crash reduction (SB)	0.000	0.000	0.660	0.740	0.370	0.000	0.780
		Calculated Value (direction 2)	Incap Crash reduction (SB)	0.460	0.903	0.330	0.230	0.000	0.371	1.560
		Enter in Safety Index spreadsheet to calculate new Safety Index (direction 2)	Post-Project Segment Directional Fatal Crashes (SB)	0.000	0.000	1.340	1.260	0.630	1.000	0.220
		Enter in Safety Index spreadsheet to calculate new Safety Index (direction 2)	Post-Project Segment Directional Incap Crashes (SB)	5.540	5.097	0.670	0.770	1.000	0.629	1.440
		Input value from updated Safety Index spreadsheet (direction 2)	Post-Project Segment Directional Safety Index (SB)	0.230	0.210	0.920	0.880	0.710	1.060	1.180
		Enter in Safety Needs spreadsheet to calculate new segment level Safety Need (direction 2)	Post-Project Segment Directional Safety Index (SB)	0.230	0.210	0.920	0.880	0.710	1.060	1.180
	SAFETY INDEX	Calculated Value - verify that it matches current performance system	Current Safety Index	1.130	1.130	1.425	1.430	1.190	1.190	2.490
	SAFETY INDEX	Enter in Safety Needs spreadsheet to calculate new segment level Safety Need	Post-Project Safety Index	1.045	0.930	0.965	0.980	0.815	0.970	0.645
	Needs	User entered value from Safety Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Original Segment Safety Need	2.157	2.157	4.259	4.259	3.334	3.334	8.268
	Needs	User entered value from Safety Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Post-Project Segment Safety Need	1.749	0.9139	0.664	0.770	0.499	0.74	0.610

				Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
				Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
LEGEND:				Project Beg MP	428	436	467	467	531	534	547
	- user entered value			Project End MP	432	440	475	475	535	547	548.75
MOBILITY	MOBILITY INDEX	Input current value from performance system	Original Segment Mobility Index		0.150	0.150	0.370	0.370	0.280	0.280	0.450
		Enter in Mobility Index Spreadsheet to determine new segment level Mobility Index	Post-Project # of Lanes (both directions)		4.00	4.00	3.00	2.00	2.00	2.00	2.00
		Input value from updated Mobility Index spreadsheet	Post-Project Segment Mobility Index		0.15	0.15	0.19	0.37	0.26	0.28	0.41
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need	Post-Project Segment Mobility Index		0.150	0.150	0.190	0.370	0.260	0.280	0.410
	FUT V/C	Input current value from performance system	Original Segment Future V/C		No change	No change	0.460	No change	0.340	No change	0.550
		Input value from updated Mobility Index spreadsheet	Post-Project Segment Future V/C		No change	No change	0.240	No change	0.320	No change	0.500
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need	Post-Project Segment Future V/C		No change	No change	0.240	No change	0.320	No change	0.500
	PEAK HOUR V/C	Input current value from performance system (direction 1)	Original Segment Peak Hour V/C (NB)		No change	No change	0.250	No change	0.170	No change	0.300
		Input current value from performance system (direction 2)	Original Segment Peak Hour V/C (SB)		No change	No change	0.250	No change	0.170	No change	0.300
		*If One-Way project, enter in Mobility Index Spreadsheet to determine new segment level Peak Hour V/C. If Two-Way project, disregard	Adjusted total # of Lanes for use in directional peak hr		N/A	N/A	N/A	N/A	N/A	N/A	N/A
		Input value from updated Mobility Index spreadsheet (direction 1)	Post-Project Segement Peak Hr V/C (NB)		No change	No change	0.130	No change	0.160	No change	0.270
		Input value from updated Mobility Index spreadsheet (direction 2)	Post-Project Segement Peak Hr V/C (SB)		No change	No change	0.130	No change	0.160	No change	0.270
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need	Post-Project Segment Peak Hr V/C (NB)		No change	No change	0.130	No change	0.160	No change	0.270
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need	Post-Project Segment Peak Hr V/C (SB)		No change	No change	0.130	No change	0.160	No change	0.270
	TTI AND PTI	Calculated Value (both directions)	Safety Reduction Factor		0.925	0.823	0.677	0.685	0.685	0.815	0.259
		Calculated Value (both directions)	Safety Reduction		0.075	0.177	0.323	0.315	0.315	0.185	0.741
		Calculated Value (both directions)	Mobility Reduction Factor		1.000	1.000	0.514	1.000	0.929	1.000	0.911
		Calculated Value (both directions)	Mobility Reduction		0.000	0.000	0.486	0.000	0.071	0.000	0.089
		Input current value from performance system (direction 1)	Original Directional Segment TTI (NB)		1.020	1.020	1.100	1.100	1.210	1.210	1.300
		Input current value from performance system (direction 1)	Original Directional Segment PTI (NB)		1.240	1.240	1.740	1.740	2.690	2.690	2.860
		Input current value from performance system (direction 2)	Original Directional Segment TTI (SB)		1.030	1.030	1.130	1.130	1.230	1.230	1.380

				Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
				Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
LEGEND:				Project Beg MP	428	436	467	467	531	534	547
	- user entered value			Project End MP	432	440	475	475	535	547	548.75
		Input current value from performance system (direction 2)	Original Directional Segment PTI (SB)		1.420	1.420	2.070	2.070	2.920	2.920	3.160
		Calculated Value (both directions)	Reduction Factor for Segment TTI		0.000	0.000	0.146	0.000	0.021	0.000	0.027
		Calculated Value (both directions)	Reduction Factor for Segment PTI		0.023	0.053	0.194	0.094	0.109	0.055	0.240
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need (direction 1)	Post-Project Directional Segment TTI (NB)		1.020	1.020	1.050	1.100	1.184	1.210	1.265
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need (direction 1)	Post-Project Directional Segment PTI (NB)		1.212	1.174	1.402	1.576	2.397	2.541	2.173
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need (direction 2)	Post-Project Directional Segment TTTI (SB)		1.030	1.030	1.065	1.130	1.204	1.230	1.343
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need (direction 2)	Post-Project Directional Segment TPTI (SB)		1.388	1.345	1.668	1.875	2.602	2.758	2.401
	CLOSURE EXTENT	Input current value from performance system (direction 1)	Orig Segment Directional Closure Extent (NB)		0.250	0.250	0.130	0.130	0.310	0.310	0.070
		Input current value from performance system (direction 2)	Orig Segment Directional Closure Extent (SB)		0.010	0.010	0.05	0.05	0.09	0.09	0.070
		Input value from HCRS	Segment Closures with fatalities/injuries		3	3	5	5	6	6	0
		Input value from HCRS	Total Segment Closures		10	10	14	14	24	24	2
		Calculated Value (both directions)	% Closures with Fatality/Injury		0.30	0.30	0.36	0.36	0.25	0.25	0.00
		Calculated Value (both directions)	Closure Reduction		0.023	0.053	0.115	0.112	0.079	0.046	0.000
		Calculated Value (both directions)	Closure Reduction Factor		0.977	0.947	0.885	0.888	0.921	0.954	1.000
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need (direction 1)	Post-Project Segment Directional Closure Extent (NB)		0.244	0.237	0.115	0.115	0.286	0.296	0.070
		Enter in Mobility Needs spreadsheet to update segment level Mobility Need (direction 2)	Post-Project Segment Directional Closure Extent (SB)		0.010	0.009	0.044	0.044	0.083	0.086	0.070
	BICYCLE ACCOM	Input current value from performance system	Orig Segment Bicycle Accomodation %		No change	No change	No change	No change	No change	2.0%	No change
		Input current value from performance system	Orig Segment Outside Shoulder width		No change	No change	No change	No change	No change	5	No change
		Input value from updated Mobility Index spreadsheet	Post-Project Segment Outside Shoulder width		No change	No change	No change	No change	No change	8	No change
		Input value from updated Mobility Index spreadsheet	Post-Project Segment Bicycle Accomodation (%)		No change	No change	No change	No change	No change	42.0%	No change
		Enter in Mobiity Needs spreadsheet to calculate new segment level Mobility Need	Post-Project Segment Bicycle Accomodation (%)		No change	No change	No change	No change	No change	45.0%	No change
	Needs	User entered value from Mobility Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Original Segment Mobility Need		0.400	0.400	0.752	0.752	3.541	3.541	0.629
		User entered value from Mobility Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Post-Project Segment Mobility Need		0.397	0.395	0.543	0.747	3.026	3.147	0.572

				Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
				Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
LEGEND:				Project Beg MP	428	436	467	467	531	534	547
	- user entered value			Project End MP	432	440	475	475	535	547	548.75
FREIGHT	TTTI AND TPTI	Input current value from performance system (direction 1)	Original Directional Segment TTTI (NB)		1.100	1.100	1.140	1.140	1.270	1.270	1.400
		Input current value from performance system (direction 1)	Original Directional Segment TPTI (NB)		1.380	1.380	1.650	1.650	2.630	2.630	3.190
		Input current value from performance system (direction 2)	Original Directional Segment TTTI (SB)		1.160	1.160	1.200	1.200	1.310	1.310	1.430
		Input current value from performance system (direction 2)	Original Directional Segment TPTI (SB)		1.580	1.580	1.990	1.990	2.270	2.270	4.090
		Calculated Value (both directions)	Reduction Factor for Segment TTTI (both directions)		0.000	0.000	0.073	0.000	0.011	0.000	0.013
		Calculated Value (both directions)	Reduction Factor for Segment TPTI (both directions)		0.011	0.027	0.097	0.047	0.054	0.028	0.120
		Enter in Freight Needs spreadsheet to update segment level Freight Need (direction 1)	Post-Project Directional Segment TTTI (NB)		1.100	1.100	1.057	1.140	1.256	1.270	1.381
		Enter in Freight Needs spreadsheet to update segment level Freight Need (direction 1)	Post-Project Directional Segment TPTI (NB)		1.364	1.343	1.490	1.572	2.487	2.557	2.807
		Enter in Freight Needs spreadsheet to update segment level Freight Need (direction 2)	Post-Project Directional Segment TTTI (SB)		1.160	1.160	1.112	1.200	1.296	1.310	1.411
		Enter in Freight Needs spreadsheet to update segment level Freight Need (direction 2)	Post-Project Directional Segment TPTI (SB)		1.562	1.538	1.797	1.896	2.146	2.207	3.599
	FREIGHT INDEX	Value from above	Original Segment TPTI (NB)		1.380	1.380	1.650	1.650	2.630	2.630	3.190
		Value from above	Original Segment TPTI (SB)		1.580	1.580	1.990	1.990	2.270	2.270	4.090
		Calculated Value	Original Segment Freight Index		0.6757	0.6757	0.549	0.549	0.408	0.408	0.275
		Calculated Value	Post-Project Segment TPTI (NB)		1.364	1.343	1.490	1.572	2.487	2.557	2.807
		Calculated Value	Post-Project Segment TPTI (SB)		1.562	1.538	1.797	1.896	2.146	2.207	3.599
		Enter in Freight Needs spreadsheet to update segment level Freight Need	Post-Project Segment Freight Index		0.683	0.694	0.609	0.577	0.432	0.420	0.312
	CLOSURE DURATION	Input current value from performance system (direction 1)	Orig Segment Directional Closure Duration (dir 1)		1466.090	1466.090	17.750	17.750	175175.610	175175.610	11.530
		Input current value from performance system (direction 2)	Orig Segment Directional Closure Duration (dir 2)		1.090	1.090	7.900	7.900	16.970	16.970	192.530
		Calculated Value	Segment Closures with fatalities		3	3	5	5	6	6	0
		Calculated Value	Total Segment Closures		10	10	14	14	24	24	2
		Calculated Value	% Closures with Fatality		0.30	0.30	0.36	0.36	0.25	0.25	0.00
		Calculated Value	Closure Reduction		0.023	0.053	0.115	0.112	0.004	0.002	0.000
		Calculated Value	Closure Reduction Factor		0.977	0.947	0.885	0.888	0.996	0.998	1.000
		Enter in Freight Needs spreadsheet to update segment level Freight Need (direction 1)	Post-Project Segment Directional Closure Duration (NB)		1433.006	1388.245	15.704	15.755	174485.580	174770.792	11.530

				Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
				Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
LEGEND:				Project Beg MP	428	436	467	467	531	534	547
	- user entered value			Project End MP	432	440	475	475	535	547	548.75
BRIDGE		Enter in Freight Needs spreadsheet to update segment level Freight Need (direction 2)	Post-Project Segment Directional Closure Duration (SB)		1.065	1.032	6.989	7.012	16.903	16.931	192.530
	VERT CLR	Input current value from performance system	Original Segment Vertical Clearance		No change	No change	No change	No change	No change	No change	No change
		Input current value from performance system	Original vertical clearance for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Input post-project value (depends on solution)	Post-Project vertical clearance for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Input post-project value (depends on solution)(force segment clearance to equal this specific bridge)	Post-Project Segment Vertical Clearance		No change	No change	No change	No change	No change	No change	No change
		Enter in Freight Needs spreadsheet to update segment level Freight Need	Post-Project Segment Vertical Clearance		No change	No change	No change	No change	No change	No change	No change
	Needs	User entered value from Freight Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Original Segment Freight Need		5.010	5.010	0.140	0.140	330.690	330.69	1.055
		User entered value from Freight Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Post-Project Segment Freight Need		4.828	4.732	0.119	0.135	329.131	329.85	0.839
	BRIDGE INDEX	Input current value from performance system	Original Segment Bridge Index		No change	No change	No change	No change	No change	No change	No change
		Input current value from performance system	Original lowest rating for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Input post-project value (For repair +1, rehab +2, replace=8)	Post-Project lowest rating for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Enter in Bridge Index spreadsheet to calculate new Bridge Index	Post-Project lowest rating for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Input updated segment value from updated Bridge Index spreadsheet	Post-Project Segment Bridge Index		No change	No change	No change	No change	No change	No change	No change
		Enter in Bridge Needs spreadsheet to update segment level Bridge Need	Post-Project Segment Bridge Index		No change	No change	No change	No change	No change	No change	No change
	SUFF RATING	Input current value from performance system	Original Segment Sufficiency Rating		No change	No change	No change	No change	No change	No change	No change
		Input current value from performance system	Original Sufficiency Rating for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Input post-project value (For repair +10, rehab +20, replace=98)	Post-Project Sufficiency Rating for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Enter in Bridge Index spreadsheet to calculate new Bridge Index	Post-Project Sufficiency Rating for specific bridge		No change	No change	No change	No change	No change	No change	No change
		Input updated segment value from updated Bridge Index spreadsheet	Post-Project Segment Sufficiency Rating		No change	No change	No change	No change	No change	No change	No change
		Enter in Bridge Needs spreadsheet to update segment level Bridge Need	Post-Project Segment Sufficiency Rating		No change	No change	No change	No change	No change	No change	No change
	BR RTNG	Input current value from performance system	Original Segment Bridge Rating		No change	No change	No change	No change	No change	No change	No change
		Input updated segment value from updated Bridge Index spreadsheet	Post-Project Segment Bridge Rating		No change	No change	No change	No change	No change	No change	No change

				Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
				Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
LEGEND:				Project Beg MP	428	436	467	467	531	534	547
	- user entered value			Project End MP	432	440	475	475	535	547	548.75
		Enter in Bridge Needs spreadsheet to update segment level Bridge Need	Post-Project Segment Bridge Rating		No change	No change	No change	No change	No change	No change	No change
PAVEMENT	% FUN OB	Input current value from performance system	Original Segment % Functionally Obsolete		No change	No change	No change	No change	No change	No change	No change
		Input updated value from updated Bridge Index spreadsheet (only remove bridge from FO if replace or rehab)	Post-Project Segment % Functionally Obsolete		No change	No change	No change	No change	No change	No change	No change
		Enter in Bridge Needs spreadsheet to update segment level Bridge Need	Post-Project Segment % Functionally Obsolete		No change	No change	No change	No change	No change	No change	No change
	Needs	User entered value from Bridge Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Original Segment Bridge Need		N/A	N/A	0.12	0.12	0.569	0.569	0.646
		User entered value from Bridge Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Post-Project Segment Bridge Need		N/A	N/A	0.12	0.12	0.569	0.569	0.646
	PAVEMENT INDEX	Input current value from performance system	Original Segment Pavement Index		No change	No change	3.66	No change	No change	No change	No change
		Input current value from performance system	Original Segment IRI in project limits		No change	No change	N/A	No change	No change	No change	No change
		Input current value from performance system	Original Segment Cracking in project limits		No change	No change	N/A	No change	No change	No change	No change
		Input post-project value (For rehab, increase to 45; for replace increase to 30)	Post-Project IRI in project limits		No change	No change	N/A	No change	No change	No change	No change
		Enter in Pavement Index spreadsheet to calculate new Pavement Index	Post-Project IRI in project limits		No change	No change	N/A	No change	No change	No change	No change
		Input post-project value (Lower to 0 for rehab or replace)	Post-Project Cracking in project limits		No change	No change	0	No change	No change	No change	No change
		Enter in Pavement Index spreadsheet to calculate new Pavement Index	Post-Project Cracking in project limits		No change	No change	0	No change	No change	No change	No change
		Input updated segment value from updated Pavement Index spreadsheet	Post-Project Segment Pavement Index		No change	No change	3.98	No change	No change	No change	No change
		Enter in Pavement Needs spreadsheet to update segment level Pavement Need	Post-Project Segment Pavement Index		No change	No change	3.98	No change	No change	No change	No change
	DIRECTION PSR	Input current value from performance system (direction 1)	Original Segment Directional PSR (NB)		No change	No change	3.35	No change	No change	No change	No change
		Input current value from performance system (direction 2)	Original Segment Directional PSR (SB)		No change	No change	N/A	No change	No change	No change	No change
		Value from above	Original Segment IRI in project limits		No change	No change	N/A	No change	No change	No change	No change
		Value from above	Post-Project directional IRI in project limits		No change	No change	N/A	No change	No change	No change	No change
		Input updated segment value from updated Pavement Index spreadsheet (direction 1)	Post-Project Segment Directional PSR (NB)		No change	No change	3.35	No change	No change	No change	No change

			Solution #	89U.1	89U.02	89U.03-A	89U.03-B	89U.05	89U.06	89U.07
			Description	Sunset Crater Safety	Antelope Hills Safety	North Cameron Safety Option A	North Cameron Safety Option B	Waterhole Canyon Freight	Waterhole Canyon Safety	Page Intersections
LEGEND:			Project Beg MP	428	436	467	467	531	534	547
	- user entered value		Project End MP	432	440	475	475	535	547	548.75
		Input updated segment value from updated Pavement Index spreadsheet (direction 2)	Post-Project Segment Directional PSR (SB)	No change	No change	4.46	No change	No change	No change	No change
		Enter in Pavement Needs spreadsheet to update segment level Pavement Need	Post-Project Segment Directional PSR (NB)	No change	No change	3.35	No change	No change	No change	No change
		Enter in Pavement Needs spreadsheet to update segment level Pavement Need	Post-Project Segment Directional PSR (SB)	No change	No change	4.46	No change	No change	No change	No change
	% FAIL	Input current value from performance system	Original Segment % Failure	No change	No change	12.5%	No change	No change	No change	No change
		Input value from updated Pavement Index spreadsheet	Post-Project Segment % Failure	No change	No change	8.3%	No change	No change	No change	No change
		Enter in Pavement Needs spreadsheet to update segment level Pavement Need	Post-Project Segment % Failure	No change	No change	8.3%	No change	No change	No change	No change
	Needs	User entered value from Pavement Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Original Segment Pavement Need	0.165	0.165	0.275	0.275	0.087	0.087	3.354
		User entered value from Pavement Needs spreadsheet and for use in Performance Effectiveness spreadsheet	Post-Project Segment Pavement Need	0.165	0.165	0.121	0.275	0.087	0.087	3.354

Performance Effectiveness Scores – Application of Multiple Crash Modification Factors

CS89U-02 (MP 436-440 Northbound)

							Effective	Current		Post-Project		Reduction				
BMP	EMP	CMF1	CMF2	CMF3	CMF4	Dir	CMF	Fatal	Incap	Fatal	Incap	Fatal	Incap		Length	Notes
436	440	0.75	0.77	1	1	NB	0.664	1	1	0.664	0.664	0.336	0.336	Segment 2 NB - night	4	striping, delineators, RPMs, and lighting
436	440	0.77	1	1	1	NB	0.770	1	0	0.770	0.000	0.230	0.000	Segment 2 NB - day	4	striping, delineators, RPMs
								1	1			0.566	0.336	Segment 2 NB		

CS89U-02 (MP 436-440 Southbound)

							Effective	Current		Post-Project		Reduction				
BMP	EMP	CMF1	CMF2	CMF3	CMF4	Dir	CMF	Fatal	Incap	Fatal	Incap	Fatal	Incap		Length	Notes
436	440	0.75	0.77	1	1	SB	0.664	0	2	0.000	1.328	0.000	0.673	Segment 2 SB - night	4	striping, delineators, RPMs, and lighting
436	440	0.77	1	1	1	SB	0.770	0	1	0.000	0.770	0.000	0.230	Segment 2 SB - day	4	striping, delineators, RPMs
								0	2			0.000	0.903	Segment 2 SB		

CS89U.03-B (MP 467-475 Southbound)

							Effective	Current		Post-Project		Reduction				
BMP	EMP	CMF1	CMF2	CMF3	CMF4	Dir	CMF	Fatal	Incap	Fatal	Incap	Fatal	Incap		Length	Notes
467	467.5	0.64	1	1	1	SB	0.640	0	0	0.000	0.000	0.000	0.000	Segment 5 SB	0.5	widen shoulders
467.5	468	0.63	1	1	1	SB	0.630	0	0	0.000	0.000	0.000	0.000	Segment 5 SB	0.5	passing lane
468	468.5	0.63	1	1	1	SB	0.630	2	0	1.260	0.000	0.740	0.000	Segment 5 SB	0.5	passing lane
468.5	469	0.77	1	1	1	SB	0.770	0	0	0.000	0.000	0.000	0.000	Segment 5 SB	0.5	striping, delineators, RPMs
469	470	0.68	1	1	1	SB	0.680	0	0	0.000	0.000	0.000	0.000	Segment 5 SB	1	widen shoulders
470	471	0.77	1	1	1	SB	0.770	0	0	0.000	0.000	0.000	0.000	Segment 5 SB	1	striping, delineators, RPMs
471	472	0.64	1	1	1	SB	0.640	0	0	0.000	0.000	0.000	0.000	Segment 5 SB	1	widen shoulders
472	474	0.77	1	1	1	SB	0.770	0	1	0.000	0.770	0.000	0.230	Segment 5 SB	2	striping, delineators, RPMs
474	475	0.64	1	1	1	SB	0.640	0	0	0.000	0.000	0.000	0.000	Segment 5 SB	1	widen shoulders
								2	1			0.740	0.230	Segment 5 SB		

CS89U.03-B (MP 467-475 Northbound)

							Effective	Current		Post-Project		Reduction				
BMP	EMP	CMF1	CMF2	CMF3	CMF4	Dir	CMF	Fatal	Incap	Fatal	Incap	Fatal	Incap		Length	Notes
467	468	0.64	1	1	1	NB	0.640	0	0	0.000	0.000	0.000	0.000	Segment 5 NB	1	widen shoulders
468	469	0.77	1	1	1	NB	0.770	0	0	0.000	0.000	0.000	0.000	Segment 5 NB	1	striping, delineators, RPMs
469	470	0.64	1	1	1	NB	0.640	0	0	0.000	0.000	0.000	0.000	Segment 5 NB	1	widen shoulders
470	471	0.77	1	1	1	NB	0.770	0	0	0.000	0.000	0.000	0.000	Segment 5 NB	1	striping, delineators, RPMs
471	472	0.64	1	1	1	NB	0.640	0	0	0.000	0.000	0.000	0.000	Segment 5 NB	1	widen shoulders
472	474	0.77	1	1	1	NB	0.770	1	1	0.770	0.770	0.230	0.230	Segment 5 NB	2	striping, delineators, RPMs
474	475	0.64	1	1	1	NB	0.640	1	0	0.640	0.000	0.360	0.000	Segment 5 NB	1	widen shoulders
								2	1			0.590	0.230	Segment 5 NB		

CS89U.06-B (MP 534-547 Northbound)

BMP	EMP	CMF1	CMF2	CMF3	CMF4	Dir	Effective CMF	Current Fatal	Current Incap	Post-Project Fatal	Post-Project Incap	Reduction Fatal	Reduction Incap		Length	Notes
534	537	0.77	0.85	1	1	NB	0.712	1	0	0.712	0.000	0.288	0.000	Segment 8 NB	3	striping, delineators, RPMs, and centerline rumble strip
537	547	0.64	0.85	1	1	NB	0.592	0	4	0.000	2.368	0.000	1.632	Segment 8 NB	10	shoulder widening and centerline rumble strip
								1	4			0.288	1.632	Segment 8 NB		

CS89U.06-B (MP 534-547 Southbound)

BMP	EMP	CMF1	CMF2	CMF3	CMF4	Dir	Effective CMF	Current Fatal	Current Incap	Post-Project Fatal	Post-Project Incap	Reduction Fatal	Reduction Incap		Length	Notes
534	537	0.77	0.85	1	1	SB	0.712	0	0	0.000	0.000	0.000	0.000	Segment 8 SB	3	striping, delineators, RPMs, and centerline rumble strip
537	547	0.68	0.85	1	1	SB	0.629	0	1	0.000	0.629	0.000	0.371	Segment 8 SB	10	shoulder widening and centerline rumble strip

Performance Effectiveness Scores – Five Performance Areas

Candidate Solution #	Candidate Solution Name	Milepost Location	Estimated Cost ($ millions)	Pavement					Bridge					Safety					Mobility					Freight				
				Existing Segment Need	Post-Solution Segment Need	Raw Score	Risk Factor	Factored Score	Existing Segment Need	Post-Solution Segment Need	Raw Score	Risk Factor	Factored Score	Existing Segment Need	Post-Solution Segment Need	Raw Score	Risk Factor	Factored Score	Existing Segment Need	Post-Solution Segment Need	Raw Score	Risk Factor	Factored Score	Existing Segment Need	Post-Solution Segment Need	Raw Score	Risk Factor	Factored Score
89U.1	Sunset Crater Safety	428-432	0.54	0.165	0.165	0.000	0.00	0.000	0.000	0.000	0.000	0.00	0.000	2.157	1.749	0.408	2.31	0.942	0.400	0.397	0.003	5.21	0.016	5.010	4.828	0.182	5.22	0.950
89U.2	Antelope Hills Safety	436-440	5.91	0.165	0.165	0.000	0.00	0.000	0.000	0.000	0.000	0.00	0.000	2.157	0.914	1.243	3.36	4.177	0.400	0.395	0.005	5.21	0.026	5.010	4.732	0.278	5.22	1.451
89U.3-A	North Cameron Safety Option A	467-475	59.68	0.275	0.121	0.154	1.80	0.277	0.120	0.120	0.000	0.00	0.000	4.259	0.664	3.595	2.24	8.053	0.752	0.543	0.209	8.39	1.754	0.140	0.119	0.021	7.55	0.159
89U.3-B	North Cameron Safety Option B	467-475	8.45	0.275	0.275	0.000	1.80	0.000	0.120	0.120	0.000	0.00	0.000	4.259	0.770	3.489	2.24	7.815	0.752	0.747	0.005	8.39	0.042	0.140	0.135	0.005	7.55	0.038
89U.5	Waterhole Canyon Freight	531-535	9.32	0.087	0.087	0.000	2.22	0.000	0.569	0.569	0.000	0.00	0.000	3.334	0.499	2.835	3.08	8.732	3.541	3.026	0.515	7.79	4.012	330.690	329.131	1.559	7.81	12.176
89U.6	Waterhole Canyon Safety	534-547	11.854	0.087	0.087	0.000	0.00	0.000	0.569	0.569	0.000	0.00	0.000	3.334	0.740	2.594	2.92	7.574	3.541	3.147	0.394	8.46	3.333	330.690	329.850	0.840	7.81	6.560
89U.7	Page Intersections	547-549	11.43	3.354	3.354	0.000	1.30	0.000	0.646	0.646	0.000	0.00	0.000	8.268	0.610	7.658	4.41	33.772	0.629	0.572	0.057	3.37	0.192	1.055	0.839	0.216	3.99	0.862

Performance Effectiveness Scores – Emphasis Areas

Candidate Solution #	Candidate Solution Name	Milepost Location	Estimated Cost ($ millions)	Safety Emphasis Area						Mobility Emphasis Area						Pavement Emphasis Area						Total Factored Benefit
				Existing Corridor Need	Post-Solution Corridor Need	Raw Score	Risk Factor	Emphasis Factor	Factored Score	Existing Corridor Need	Post-Solution Corridor Need	Raw Score	Risk Factor	Emphasis Factor	Factored Score	Existing Corridor Need	Post-Solution Corridor Need	Raw Score	Risk Factor	Emphasis Factor	Factored Score	
89U.1	Sunset Crater Safety	428-432	0.54	0.351	0.347	0.004	2.31	1.50	0.014	0.254	0.254	0.000	5.21	1.50	0.000	0.600	0.600	0.000	0.00	1.50	0.000	1.922
89U.2	Antelope Hills Safety	436-440	5.91	0.351	0.341	0.010	3.36	1.50	0.050	0.254	0.254	0.000	5.21	1.50	0.000	0.600	0.600	0.000	0.00	1.50	0.000	5.704
89U.3-A	North Cameron Safety Option A	467-475	59.68	0.351	0.324	0.027	2.24	1.50	0.091	0.254	0.233	0.021	8.39	1.50	0.264	0.600	0.548	0.052	1.80	1.50	0.140	10.737
89U.3-B	North Cameron Safety Option B	467-475	8.45	0.351	0.324	0.027	2.24	1.50	0.091	0.254	0.254	0.000	8.39	1.50	0.000	0.600	0.600	0.000	1.80	1.50	0.000	7.986
89U.5	Waterhole Canyon Freight	531-535	9.32	0.351	0.319	0.032	3.08	1.50	0.148	0.254	0.251	0.003	7.79	1.50	0.035	0.600	0.600	0.000	2.22	1.50	0.000	25.102
89U.6	Waterhole Canyon Safety	534-547	11.854	0.351	0.332	0.019	2.92	1.50	0.083	0.254	0.254	0.000	8.46	1.50	0.000	0.600	0.600	0.000	0.00	1.50	0.000	17.551
89U.7	Page Intersections	547-549	11.43	0.351	0.331	0.020	4.41	1.50	0.132	0.254	0.253	0.001	3.37	1.50	0.005	0.600	0.600	0.000	1.30	1.50	0.000	34.963

Performance Effectiveness Scoring – Results

Candidate Solution #	Candidate Solution Name	Milepost Location	Estimated Cost ($ millions)	Risk Factored Benefit Score					Risk Factored Emphasis Area Scores			Total Factored Benefit	F_{VMT}	F_{NPV}	Performance Effectiveness Score
				Pavement	Bridge	Safety	Mobility	Freight	Safety	Mobility	Pavement				
89U.1	Sunset Crater Safety	428-432	0.54	0.000	0.000	0.942	0.016	0.950	0.014	0.000	0.000	1.922	1.42	15.3	77.5
89U.2	Antelope Hills Safety	436-440	5.91	0.000	0.000	4.177	0.026	1.451	0.050	0.000	0.000	5.704	1.42	15.3	21.0
89U.3-A	North Cameron Safety Option A	467-475	59.68	0.277	0.000	8.053	1.754	0.159	0.091	0.264	0.140	10.737	2.79	20.2	10.1
89U.3-B	North Cameron Safety Option B	467-475	8.45	0.000	0.000	7.815	0.042	0.038	0.091	0.000	0.000	7.986	2.79	15.3	40.3
89U.5	Waterhole Canyon Freight	531-535	9.32	0.000	0.000	8.732	4.012	12.176	0.148	0.035	0.000	25.102	0.57	20.2	31.1
89U.6	Waterhole Canyon Safety	534-547	11.854	0.000	0.000	7.574	3.333	6.560	0.083	0.000	0.000	17.551	1.92	15.3	43.5
89U.7	Page Intersections	547-549	11.43	0.000	0.000	33.772	0.192	0.862	0.132	0.005	0.000	34.963	0.36	20.2	22.3

Appendix J: Solution Prioritization Scores

Candidate Solution #	Candidate Solution Name	Milepost Location	Estimated Cost ($ millions)	Pavement		Bridge		Safety		Mobility		Freight		Total Factored Score	Risk Factors					Weighted Risk Factor	Segment Need	Prioritization Score
				Score	%	Score	%	Score	%	Score	%	Score	%		Pavement	Bridge	Safety	Mobility	Freight			
89U.1	Sunset Crater Safety	428-432	0.54	0.000	0.0%	0.000	0.0%	0.956	49.8%	0.016	0.8%	0.950	49.4%	1.922	1.14	1.51	1.78	1.36	1.36	1.569	1.15	140
89U.2	Antelope Hills Safety	436-440	5.91	0.000	0.0%	0.000	0.0%	4.227	74.1%	0.026	0.5%	1.451	25.4%	5.704	1.14	1.51	1.78	1.36	1.36	1.671	1.15	40
89U.3-A	North Cameron Safety Option A	467-475	59.68	0.418	3.9%	0.000	0.0%	8.144	75.8%	2.018	18.8%	0.159	1.5%	10.737	1.14	1.51	1.78	1.36	1.36	1.670	1.31	22
89U.3-B	North Cameron Safety Option B	467-475	8.45	0.000	0.0%	0.000	0.0%	7.906	99.0%	0.042	0.5%	0.038	0.5%	7.986	1.14	1.51	1.78	1.36	1.36	1.776	1.31	94
89U.5	Waterhole Canyon Freight	531-535	9.32	0.000	0.0%	0.000	0.0%	8.880	35.4%	4.047	16.1%	12.176	48.5%	25.102	1.14	1.51	1.78	1.36	1.36	1.509	1.62	76
89U.6	Waterhole Canyon Safety	534-547	11.854	0.000	0.0%	0.000	0.0%	7.658	43.6%	3.333	19.0%	6.560	37.4%	17.551	1.14	1.51	1.78	1.36	1.36	1.543	1.62	109
89U.7	Page Intersections	547-549	11.43	0.000	0.0%	0.000	0.0%	33.904	97.0%	0.197	0.6%	0.862	2.5%	34.963	1.14	1.51	1.78	1.36	1.36	1.767	1.69	67

Appendix K: Preliminary Scoping Reports for Prioritized Solutions *(to be added for Draft Report)*